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GEOLOGICAL SURVEY OF OHIO

J. A. BOWNOCKER, State Geologist

FOURTH SERIES, BULLETIN 31

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GEOLOGY OF VINTON COUNTY

By WILBER STOUT

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INTRODUCTION

Vinton County was settled in 1802 when cabins were erected and clearings made largely in Elk and Vinton townships. The region soon became prominent through the discovery of buhrstone which was plentiful in the hills along Raccoon Creek and its western tributaries and which was first quarried and worked into millstones about the year 1807. This was the first industry in the county and the product known as Raccoon millstone found a ready and extensive market. For more than thirty years the revenue from the quarries alone was not less than \$20,000 annually. The business caused an influx of workmen, hence McArthur town, laid out in November, 1815, rapidly developed into a thriving village. Vinton County was finally organized as a separate division of the State, March 23, 1850, from parts of Athens, Hocking, Ross, Jackson, and Gallia counties.

The mineral resources next to be worked in a vigorous way were the iron ores, the demand for which became active with the erection of Eagle Furnace in 1852, Vinton, Cincinnati, and Hope in 1853, Hamden in 1854, and Zaleski in 1858. These furnaces were operated successfully for more than twenty years. The trade in iron ores, however, continued brisk until 1888, after which it declined rapidly.

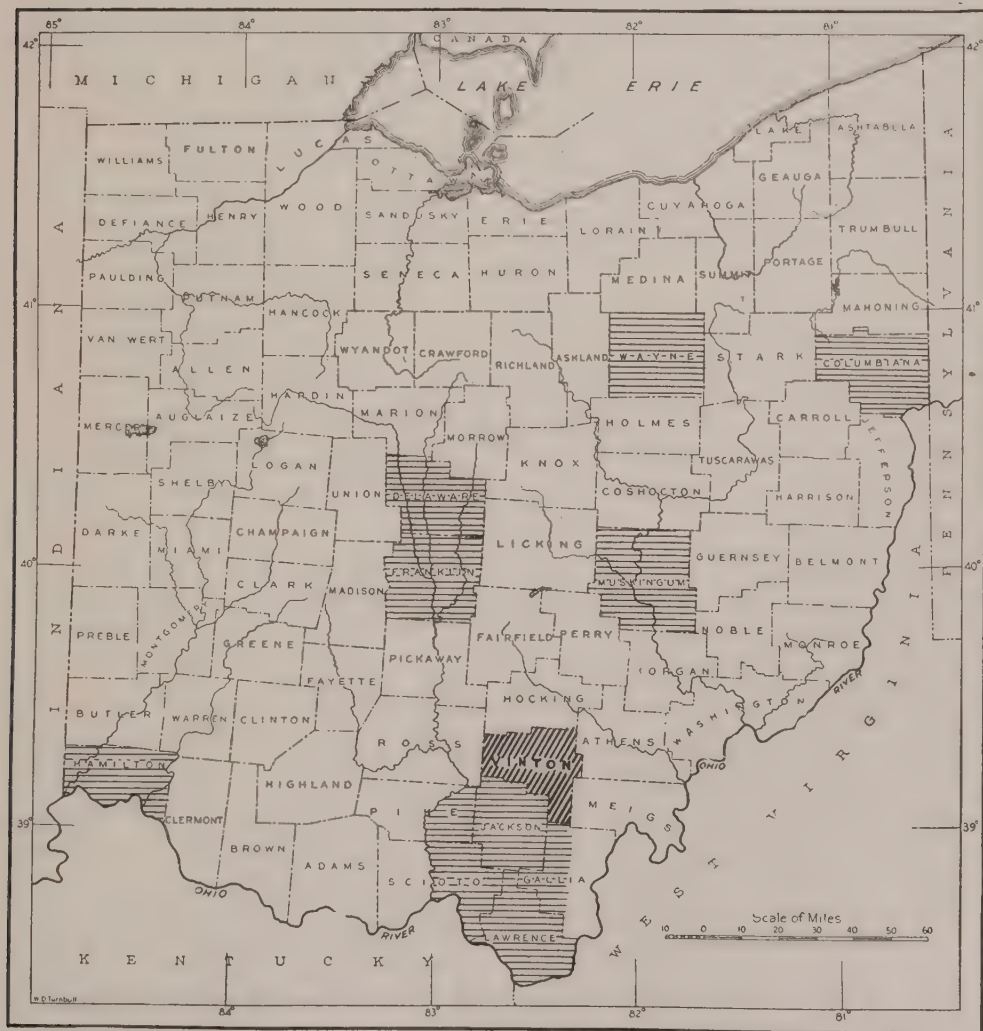
Coal mining, on a large scale, began soon after the completion of the Marietta and Cincinnati Railroad (now the Baltimore and Ohio) in 1856 and was further extended by the construction of the Ohio and West Virginia Railroad (now the Hocking Valley) in 1880. The search for oil and gas in Vinton County began in 1867 but results were not especially favorable until the large Clinton gas field was opened about 1899 in the western part of the area. Since then drilling has been active and great quantities of gas have been taken from deep-seated rocks. Some oil also has been secured.

The limestones of the county have been of value not only for industrial purposes but more, through their decay, for soil enrichment. The calcareous soils are excellent for fruit and grazing. Native clays were first turned to profitable account about 1845 when stoneware shops were built on Potters Ridge and at other places within the county. The ware was turned by hand on the potters' wheel and burned in small kilns with wood as fuel. Such factories were operated until 1903. The ceramic industry, however, was established on a modern basis with the erection of a brick plant at McArthur in 1905 and another at Hamden in 1908. The local sandstones were used for constructing bridges, furnaces, and mills.

The future development of Vinton County through its natural resources is assured, as it is especially rich in clays and coals. The clays have high purity, occur in large quantities, and are well distributed. The coal reserve is large, amply sufficient for all domestic and industrial needs for many years.

LOCATION AND AREA

Vinton County is located in the southern part of the State. It lies between the Scioto and Hocking rivers or more definitely at the



Map I. Shows the position of Vinton County in the State, and other counties for which bulletins have been issued by the Geological Survey of Ohio.

headwaters of Raccoon Creek and eastern tributaries of Salt Creek. Its position is between parallels $39^{\circ} 1'$ and $39^{\circ} 24'$ north and meridians $82^{\circ} 15'$ and $82^{\circ} 46'$ west. Vinton County is bounded on the north

by Hocking, on the west by Ross, on the south by Jackson and Gallia, and on the east by Meigs and Athens counties. It is composed of twelve townships. Elk, Vinton, Knox, and Madison townships were secured from Athens County; Jackson, Swan, and Brown from Hocking County; Harrison and Eagle from Ross County; Richland and Clinton from Jackson County; and Wilkesville from Gallia County. According to the latest figures of the Government, the total area of Vinton County is 415 square miles, giving it a rank of 62nd in size in the State.

CHAPTER I

PHYSIOGRAPHY

INTRODUCTION

In order to appreciate the physiography or surface features of Vinton County some attention should be given to the cause of its relief and the various forces which are at work modifying it. Some of these agencies are quite apparent but others are more vague. Most of them, however, have left certain imprints on the surface such as poorly drained valleys; narrow, constricted gorges; flat-topped ridges; and broad terraces through which the history of the region is at least partially revealed. Preceding the work of the dynamic agencies in carving the land to its present form, however, came the building of the various rock strata by physical and chemical processes and then their elevation to land surfaces by diastrophic forces.

All the consolidated rocks now appearing at the surface in Vinton County are of sedimentary origin, and were laid down in or by the agency of water. Most of them were deposited in the sea, but some were formed in extensive marshes, either brackish or fresh water. In general, during these periods the floors of the basins were slowly subsiding, thus allowing the successive accumulation of strata in great thickness.

Shales were formed from silts and sandstones from sands that were carried by streams into the basins from highland areas in which older rocks were undergoing decay. Through differential separation by moving water the sand was deposited near the mouths of streams and along the shores of the basins, whereas the finer materials were carried farther away to the deeper or to the more quiet places. By consolidation the sand became sandstone and the silt became shale. The substances that form the limestones, both marine and fresh water, were precipitated from the water or gathered from the soluble matter of the seas or lakes by lime-secreting animals and plants that flourished where the conditions of light, warmth, food, etc. were favorable for their growth and multiplication. As the organisms died, the calcareous parts of their bodies settled to the bottom and subsequent changes consolidated the matter to firm rock. Plant life that grew in marshy places, where it was preserved under certain conditions of humidity, produced the coal.

The beds were thus laid down, horizontally or nearly so, on the basin floors in extensive and successive sheets. The different rock

building processes, acting through long periods known as the Mississippian and the Pennsylvanian, finally accumulated the thick mass of strata now appearing at the surface of Vinton County. These rocks, however, remained beneath the water until the great revolution in late Permian time which produced the Appalachian Mountains and the wide plains to the west bordering the major uplift. The force was so great that the strata were not only elevated but were bent, tilted, and locally faulted. Further uplifting occurred again in Cretaceous and Tertiary times.

The combined thickness of the various strata which appear at the surface somewhere in Vinton County is approximately 1,360 feet. These rocks belong to the Mississippian and Pennsylvanian systems. The drill has yielded some information regarding the deep-seated rocks from the lower part of the Mississippian on through the Devonian and Silurian to about the middle of the Ordovician. The thickness of sedimentary rocks thus known in Vinton County is close to 5,000 feet.

Directly upon the establishment of land surfaces the many destructive forces of nature, such as streams, weathering, solution, etc., began disintegrating and removing recently elevated rocks. If this process had continued to completion all the land would have been reduced to sea level. This was not the case but it proceeded far enough to modify the surface of the entire area. Extensive plains standing but slightly above sea level called peneplains were formed along drainage lines, whereas hills of conspicuous elevation, called monadnocks, were left along main divides. Two peneplains and a strath, which is an immature cycle of erosion producing only broad valleys, are evident in Vinton County. These will be treated at greater length under Surface Features.

DIP OF STRATA

The surface rocks in Vinton County have a rather uniform dip both east and south. The eastern dip is much greater than the southern. The inclination of strata is not local but regional as it is present throughout all eastern and southern Ohio. The main syncline, in a general way, is along the Ohio River as the rocks in Ohio and in West Virginia both dip in that direction.

Dip to the east.—The average dip of the rocks to the east, as measured by the Lower Mercer limestone and the Clarion coal, is about 25 feet per mile in northern Vinton County. It appears also to be fairly constant. In the central part of the area the dip varies somewhat but is about 27 feet per mile. The irregularities are local in extent and are not large. In the southern part of the county the eastward inclination of the rocks increases to nearly 32 feet per mile.

The mean dip of the strata to the east in Vinton County is thus about 28 feet per mile, the maximum about 40 feet, and the minimum nearly 18 feet.

Dip to the south.—In western Vinton County the southerly dip of the rocks is nearly 14 feet per mile, in the central part it is approximately 12 feet, and in the eastern part it is about 10 feet. The mean southern inclination of strata throughout the entire county is about 12 feet per mile and it is rather uniform. The maximum and minimum dips in this direction, except for minor variations, is 18 and 8 feet per mile. No anticlines except very local ones with small elevations are present within Vinton County.

The greatest dip of the strata in the area is in the general direction of a line $23^{\circ} 12'$ south of east along which the average inclination is 33 feet per mile. The strike of the rocks which is at right angles to the dip is therefore $23^{\circ} 12'$ east of north.

RELIEF

Irregularities or inequalities of land surface, considered collectively, is known as the relief of a region. The chief features of Vinton County are long lines of rather rugged hills, and narrow valleys separating them. No pronounced difference between one area and another is evident, not enough at least to warrant dividing the county into subdivisions. The variations are minor and local. The most rugged hill lands are found in the eastern part of the county in Brown, Knox, Madison, and Vinton townships and in the western part in Eagle, Harrison, Jackson, and Richland townships. This is due to several causes, the chief of which are the character of the rock strata, immaturity of drainage, and positions of original water divides. Where the present streams have cut from one preglacial valley to another or where they have been deflected along minor tributaries of the original drainage, bordering hills are usually steep and bold. This is especially true where a large part of the strata dissected are massive sandstones. Examples of this rugged type of topography along constricted valleys are found along Raccoon Creek in the northwestern part of Brown Township, in northeastern Elk Township, and from Hope past Moonville, Knox, Bolin's Mills, and Arbaugh to Hawk or even to Minerton. Conditions are much the same also along Elk Fork from Vinton Furnace to its junction with Raccoon Creek, along Wheelabout Creek south of Zaleski, and along Pierce Run from Oretton to Radcliff. The rough hills along Sandy and Little Sandy runs in Brown Township, along Tedroe and Russell runs in Knox, along Alman and Zinns runs in Vinton, and along Rockcamp and Indiancamp runs in Wilkesville are due to deepening of the valleys caused by changes in drainage

elsewhere and to the presence of massive sandstones and resistant shales in bordering walls.

Factors most effective in developing a rough topography in Jackson, Eagle, Harrison, and Richland townships are, first, the character of the rock strata which for the most part are siliceous shales and sandstones of the Cuyahoga, Logan, and Pottsville formations, and second, the mature dissection of the region by streams which have been but little deflected but much rejuvenated by changes in the major drainage during glacial time. Most of the streams are now following the same courses that they did originally, but owing to changes elsewhere they were allowed to cut deeper into the country rock. The shales and sandstones in these formations are above the average in resistance to weathering, that is, they disintegrate slowly. On this account the streams have cut long, narrow valleys with many lateral intrenchments. In general, both medial and branch ridges are long and slender and terminate sharply. Broad uplands are seldom found in this part of the county. For the most part it is typical Waverlian topography.

In the central part of Vinton County in Swan, Elk, Clinton, and parts of adjacent townships, the country is less rugged. The hills are not so high and have longer slopes, whereas the ridges are wider. Two factors are evident. One of these is that the strata are largely shales, clays, and friable sandstones which are not especially resistant to weathering, and the other is that the region was traversed by several rather large preglacial streams which had cut wide valleys and effectively reduced the bordering highlands. Further, since that time the present streams have not been able to greatly deepen their channels as the sediments in the old beds have blocked their progress. Another region with similar topography is found in the southeastern part of Wilkesville Township.

The most elevated lands in Vinton County are the ridges in western Eagle Township in sections 7, 18, 19, 30, and 31. These ridges rise to more than 1,100 feet above tide and their highest knobs to 1,140 to 1,220 feet. As this group of hills lies close to one of the main drainage systems, the Scioto River, they have also the greatest relief. The plains along the streams here are 630 to 700 feet above tide, thus making the relief 450 to 550 feet or more. In western Harrison Township the medial ridges rise to about 1,100 feet or to approximately 460 feet above the valley plains.

East of this through Jackson, eastern Harrison, and Richland townships the relief is less, as the main water divide in which the streams rise extends nearly north and south through Jackson and Richland townships, and as erosion in this area has been sufficiently severe to reduce the ridges to 1,050 feet or less above sea. In a few localities, for example near Stella, prominent knobs have elevations of approximately 1,100 feet. The general relief in Vinton County is least in

Swan, Elk, and Clinton townships where few of the main ridges rise much above 1,000 feet and where the valley floors are 700 feet or more above tide, for which the influence of preglacial streams is largely responsible. Little variation, except local modification, is shown throughout Brown, Madison, Knox, Vinton, and Wilkesville townships. The heights above sea of the dividing ridges approximate 1,000 to 1,050 feet and that of the lateral ridges 900 to 950 feet. The plains along the major stream, Raccoon Creek, vary in elevation from 620 feet in southern Wilkesville Township to 760 feet in northern Brown.

In general, the relief in Vinton County is about an average for that in southern Ohio as it represents the normal inequalities of surface in both the Mississippian and Pennsylvanian groups of rocks. It shows neither extreme and nowhere prominent deviations.

HILLS AND UPLANDS

Owing to the mature dissections of Vinton County, the highlands consist of long, narrow ridges which are greatly indented by hollows and gullies where small streams have worked their way up the slopes. This gives rise to many minor projections on both medial and lateral ridges which present thus a very rugged or serrated appearance. The summits of the ridges, however, are not especially irregular in outline as few of them have been reduced far below the old peneplain stages. A prominent round-knob topography from weathering and erosion is not evident in any locality. The knobs, with few exceptions, are not high or steep and seldom rise more than 50 feet above the general level of the main ridge. Wide, gently rolling uplands such as are found in eastern Ohio are not present in Vinton County. Those most nearly approaching this condition are found in local areas in Knox, Madison, Vinton, and Wilkesville townships where the rocks are largely soft shales and friable sandstones of lower Conemaugh age. Further, where such strata predominate, the slopes of the hills are more gentle and are often well terraced. Such areas afford excellent lands for pasturage and fruit raising.

In Swan, Elk, and Clinton townships the hills are usually 200 to 300 feet in height, have moderate slopes, and have well-rounded summits. The dissection is mature, giving rise to long lines of medial ridges with many laterals. The rocks are largely shales, soft sandstones, and clays of the lower Allegheny and upper Pottsville formations. Soil derived from such strata is rather lean but it responds readily to fertilization.

In western Vinton County in Jackson, Eagle, Harrison, and Richland townships the ancient highland plains have been so completely dissected by major streams and their tributaries that the remnants

appear as a network of long ridges with narrow summits and with steep slopes. The hillsides are also indented with many ravines and gullies. The usual relief is between 300 and 500 feet. Shales and sandstones of Cuyahoga, Logan, and Pottsville age on reduction leave a poor residual soil. Farming is largely confined to summits of the ridges and to valleys. The hillsides are left for forests or are used for pasturage.

VALLEY PLAINS AND TERRACES

The most prominent and valuable valley plains in Vinton County are along Salt Creek and Pike Run in Eagle Township and along Middle Fork of Salt Creek in Harrison. Next to these are the preglacial valleys from Hamden to Dundas and from there northeastward toward Zaleski and northward past McArthur to Creola. The valley of Raccoon Creek broadens only locally. Its plains are moderately wide in southeastern Swan Township and from Zaleski to Hope in northern Madison and southwestern Brown. From Hope through Brown, Knox, Vinton, and Wilkesville townships to Ewington, Gallia County, the Raccoon Valley is narrow except where meanderings of the stream or the influence of tributaries have caused expansion in local areas.

Salt Creek Valley from the Vinton-Ross county line in Section 6, Harrison Township, to its convergence with that of Pretty Run in Section 22, Eagle Township, averages more than .5 mile in width. The variation is not large, being from about .3 to .8 mile. The gradient is close to 5 feet per mile. These plains are quite level except for low terraces which are usually local in extent. The valley of Pike Run from its junction with that of Salt Creek in Section 29, Eagle Township, to Jintown, in Section 8, has an average width which is quite uniform of nearly .3 mile. The terraces are all low except remnants of the old preglacial valley, or Parker strath stage, which are clearly defined in the central parts of sections 30 and 29. The valley of Salt Creek from Eagle Mills northward narrows gradually to the col at the Pine Cottage School in Section 36, Salt Creek Township, Hocking County, where it is gorge-like in character. The plains along Pretty Run and its tributaries are generally narrow and uniform or they are about normal for streams in the Waverly group of rocks. Remnants of the floor of the preglacial stream are evident in the northern part of Section 23, Eagle Township. The most fertile land in Vinton County is that along Salt Creek, Pike Run, and Pretty Run. The soil is a light alluvium, very rich and well drained.

The lowlands along Middle Fork of Salt Creek in Harrison Township are very erratic in width, owing to meanderings of the stream and to deflections caused by preglacial drainage. From West Junc-

tion through the northern parts of sections 31 and 32, Harrison Township, to the central part of Section 33, the valley is narrow and constricted, averaging not more than .25 mile in width. From Section 33 through sections 28, 21, 15, 14, 11, and 12 to the Harrison-Richland township line the valley plains average nearly .5 mile in width and locally expand to as much as 1 mile. Remnants of the old preglacial valley floor, now represented by high terraces, are present in northwestern Section 28, northern Section 21, northeastern Section 15, and western Section 12. Outlying round knobs more than 150 feet high are found in the central part of Section 21 and in the northwestern part of Section 14. The soil on the low-lying plains is an alluvial silt, rich and well drained, whereas that on the high terraces is a clay, highly leached and not especially productive.

The preglacial valley extending northward from Hamden to Dundas in Clinton Township averages nearly .6 mile in width but the floor is considerably dissected and locally terraced by present streams. The soil is a clay or sandy silt, both highly leached and generally sour, as the drainage is poor. The plains along Little Raccoon Creek northwest of Hamden are narrow but are made up of sandy silts of good quality. Small but well preserved terraces are especially prominent along this stream in sections 7 and 18, Clinton Township. Along the preglacial valley extending northeastward from Dundas to Zaleski and along that extending northward from Dundas, past McArthur, Elk Fork, Creola, and Orland to New Plymouth, the lowlands average about .3 mile in width. Some expansions are found where tributaries joined former streams and where present waterways have cut into adjacent uplands. Since both the preglacial and present streams have been active here, these plains are very uneven in elevation and show a variety of soil. The predominant soil on the plains of the preglacial streams is a clay, highly leached and poor, whereas that on lowlands of present streams is a sandy alluvium of good quality.

The plains along Raccoon Creek in its entire passage of nearly 59 miles across Vinton County are exceptionally narrow for a stream of this size as they average less than .2 mile and seldom expand to as much as .4 mile. In many places the valley is very constricted, thus limiting the lowlands to narrow, ribbon-like belts bordering first one, then the other side of the stream. This is especially true of the Raccoon plains from Moonville past Knox, Bolin's Mills, Vales Mills, and Arbaugh to Radcliff. The soil on them is a sandy silt, which for the most part is quite fertile. Raccoon Valley is widest along the upper part of the course from New Plymouth to Hope where it averages about .3 mile. The increase here is due to the influence of preglacial streams which flowed southward toward Dundas and which

left their imprints by high terraces at many places. The stream is generally sluggish and much of the lowland swampy. From Radcliff southward to the Vinton-Gallia county line, the plains along Raccoon Creek are narrow, averaging little more than .2 mile. The soil is a sandy silt of fair quality. Elk Fork is another stream whose plains are exceptionally narrow for its size. They are best developed and of most value along the upper part of the course in Elk Township.

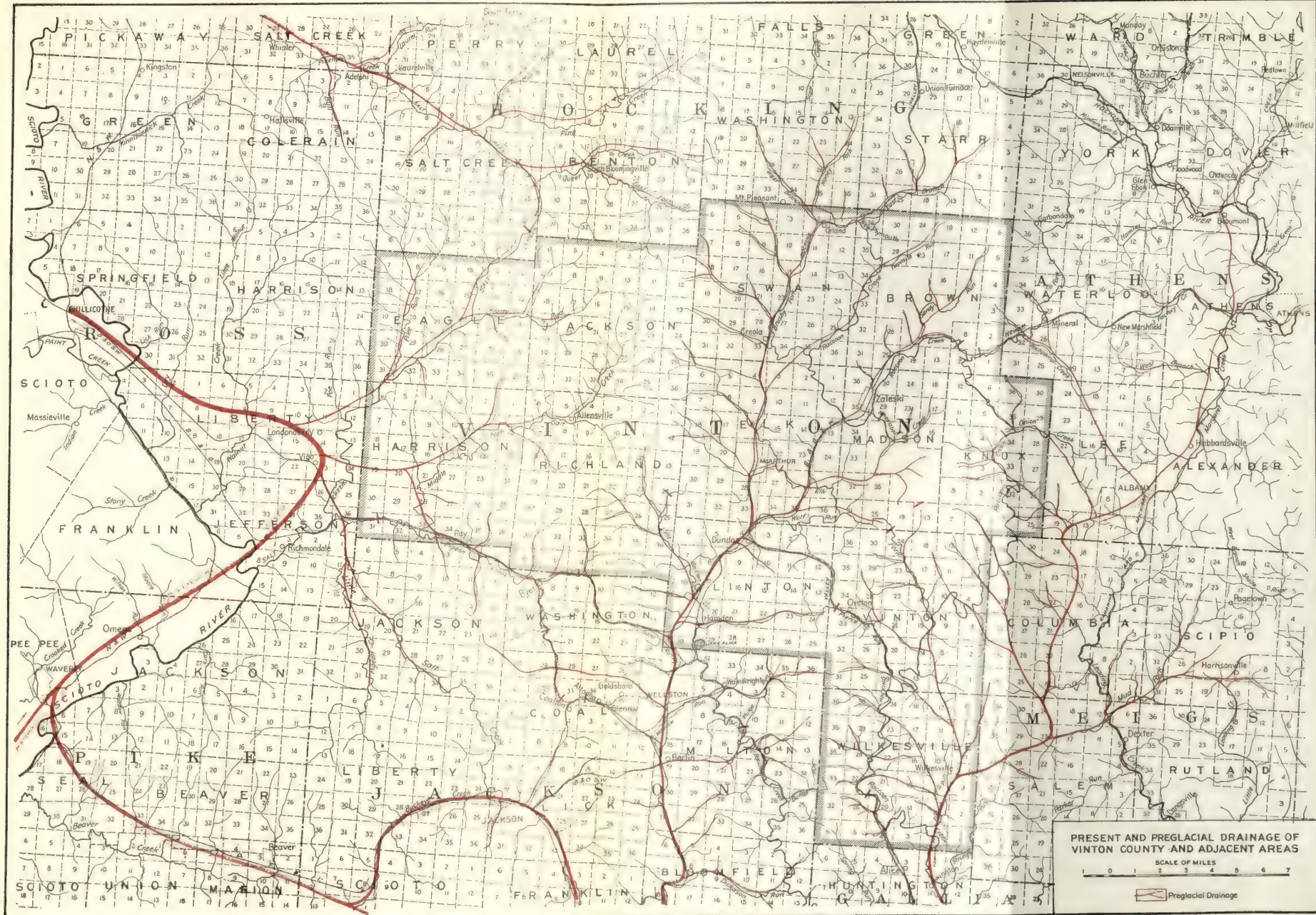
DRAINAGE

Present Streams

Ohio River receives through Scioto River and through Raccoon Creek the run-off from all of Vinton County. Raccoon Creek, the largest through-flowing stream, drains Brown, Swan, eastern Jackson, eastern Richland, Clinton, Elk, Madison, Knox, Vinton, and Wilkesville townships or an area of 291 square miles. Salt Creek, a tributary of Scioto River, drains western Jackson, Eagle, western Richland, and Harrison townships or 124 square miles.

Raccoon Creek is formed from two branches which unite south of New Plymouth in Section 36, Brown Township. One of these, West Branch, rises to the northwest in central Washington Township, Hocking County, and the other, East Branch, heads to the northeast in central Starr Township, Hocking County. From New Plymouth, Raccoon Creek flows southward through the western part of Brown Township to Section 32 where it is deflected southwestward across the corner of Swan Township. In Brown Township, the only tributary of much size is Twomile Run which drains a few square miles in the north central part. Brushy Fork which joins Raccoon Creek in central Section 35, Swan Township, is more important as it drains most of Swan Township and northeastern Jackson. Southward from Swan Township the course of Raccoon Creek is very erratic for a distance of more than 12 miles or to Hope in Brown Township. It makes large bows which are caused by the deflection of the stream from one preglacial valley to another. The course is southeastward across the corner of Elk Township, thence northward past Zaleski in Madison Township to Section 25, Brown Township, where the stream has so doubled back on itself that the distance across the bow is only about one-sixth of that around the loop. Wheelabout Creek, rising in northeastern Madison Township, and entering Raccoon Creek near Zaleski, is the largest tributary in this part of the basin.

Through southern Brown Township the course of Raccoon Creek is northeastward to Hope, thence southeastward past Moonville to Section 12, Knox Township. The largest tributaries are Hewett



Fork rising near Carbondale, Athens County, and joining Raccoon Creek near Moonville, and Sandy Run which drains the central part of Brown Township and joins the major stream near Hope. From Moonville the general direction of flow of Raccoon Creek is southeastward to the village of Knox in Section 35, Knox Township, thence with many flexures southward past Bolin's Mills and Vales Mills to Section 4, Vinton Township, where the stream with many meanders is deflected westward to Arbaugh. From Moonville to Arbaugh the laterals are all small, the most important being Onion Creek, Flat Run, and Brush Fork from the east and Tedroe, Merritt, Russell, and Long runs from the west.

In northeastern Section 15, Vinton Township, Raccoon Creek is joined by Elk Fork, the largest tributary it receives in Vinton County. Elk Fork rises in Section 24, Jackson Township, and flows southeastward through Elk, southwestern Madison, and central Vinton townships. The length of the stream is 20 miles and the gradient 13.5 feet per mile. It drains an area of 60 square miles which is small for a stream of that length. This is due to the fact that Elk Fork is made up most largely of what were small tributaries of the preglacial streams. Its tributaries are all small, the largest being Puncheon Fork, Wolf, Flat, and Alman runs. Raccoon Creek from central Vinton Township flows with many flexures southward past Hawk and Clarion to Minerton in Wilkesville Township, thence southeastward into Gallia County near Ewington. In this part of the basin the eastern tributaries are Zinns and Flatlick runs and the western laterals are Pierce, Rockcamp, Indian camp, and Karr runs.

From the place in Section 36, Brown Township, where Raccoon Creek is formed by the union of East Branch and West Branch to where it leaves the county in Section 2, Wilkesville Township, the distance in a direct line is 24 miles but the course of the stream through the many meanderings is 59 miles or nearly two and one-half times as much. The gradient of the stream is only 2.5 feet per mile. On this account Raccoon Creek throughout most of its course is very sluggish and the valley much filled with silt and sand which have been brought in by the more active tributaries. Rapids or riffles are short in length and few in number. The largest are confined to the upper course of the stream in western Brown Township. Most of the peculiarities of Raccoon Creek are due to the influence of preglacial drainage, the present stream occupying parts of several of the older valleys. Aside from its tributaries, Elk Fork and Little Raccoon Creek, the major stream drains an area in Vinton County of 193 square miles.

Little Raccoon Creek heads in the hills in Section 2, Richland Township, flows southward across eastern Richland, thence southeastward across southwestern Clinton, and enters Jackson County

near Lake Alma. From this place its general course is southeastward across Milton and Bloomfield townships, Jackson County, and Huntington Township, Gallia County. It unites with the main stream about 2 miles south of Vinton. Little Raccoon Creek in Vinton County has a length of nearly 12 miles and drains an area of 38 square miles in eastern Richland, southwestern Elk, and western Clinton townships. In Richland Township it is free flowing but in Clinton it is sluggish and silt laden owing to the influence of preglacial streams. Tributaries are small, the most important being McConnel, Johnson, and Tripp runs.

Salt Creek is the largest stream in western Vinton County. It flows in a deeply entrenched valley and with its tributaries is actively engaged in reducing the highlands which are now maturely dissected. This stream rises in northwestern Hocking and southeastern Pickaway counties, flows southeastward across western Hocking County, and enters Vinton County in Section 11, Eagle Township. From this place its course is deflected southwestward across the central part of Eagle and the northwestern corner of Harrison townships into Liberty Township, Ross County, thence southward across Liberty and southwestward across Jefferson townships to the Scioto River near Richmondale. The area drained in Vinton County is 44 square miles which includes most of Eagle, northwestern Jackson, and northwestern Harrison townships. The length of this part of the course is 9 miles and the gradient is about 4.5 feet per mile. Pike Run which drains northwestern Eagle Township and Pretty Run which drains northeastern Eagle and northwestern Jackson townships are the largest tributaries.

Middle Fork of Salt Creek rises on the uplands in central Jackson Township, Vinton County, flows southwestward across the northwestern corner of Richland Township, thence with many meanderings on southwestward across Harrison Township into Ross County where it unites with Salt Creek near West Junction. In Vinton County this basin covers central and southern Jackson, southeastern Eagle, western Richland, and eastern and southern Harrison townships. The area drained is 80 square miles. The length of the stream in Vinton County is nearly 22 miles and the gradient not far from 16.6 feet per mile. Noteworthy features are the abnormal contraction and expansion of the valley and the erratic meanderings of the stream in Harrison Township, both due largely to the influence of older drainage systems. The largest tributary is Pigeon Creek, which, however, drains only small areas in southeastern Harrison and southern Richland townships. Other laterals are Stevens Branch, Riley Run, and Kelley Branch. Both the main stream and its larger tributaries throughout most of their courses flow on or not far above bedrock and are degrading their valleys.

Preglacial Drainage

Regional drainage

Before the advent of the great glaciers in North America in Pleistocene time all southern Ohio and adjacent parts of West Virginia and Kentucky were drained by a system of rivers the general trends of which were northward instead of westward, as are those now present in the area.¹ Of these the master stream was the Chillicothe River which was formed at Waverly by the union of the Teays and Portsmouth rivers, and which flowed northward from this place, past Omega, Richmondale, Vigo, Londonderry, Chillicothe, and Circleville to the northern part of Pickaway County, where it was joined by the Newark River rising far to the east in Coshocton County. The Teays River rose in the New River Basin in North Carolina and Virginia and flowed northwestward past Charleston and St. Albans, thence westward along the route now followed by the Chesapeake and Ohio Railway past Milton and Barboursville to the present valley of the Ohio River at Huntington. From this place its course was much the same as that of the present stream, the Ohio River, to Wheelersburg, Ohio, where the two courses change radically. The present stream flows westward towards Portsmouth and Cincinnati whereas the preglacial Teays River continued northward past Harrisonville, Stockdale, Glade, Beaver, and Givens to Waverly where it united with the Portsmouth River to form the Chillicothe, the major stream. The headwaters of the old Portsmouth River were near Manchester, in southern Adams County, Ohio, and in northern Lewis County, Kentucky. This river flowed eastward, along the present valley of the Ohio River, past Rome, Vanceburg, and Buena Vista to Portsmouth, thence northward, along that of the Scioto River, past Lucasville, Wakefield, and Piketon to Waverly where it united with the Teays River to form the Chillicothe.

In southern Ohio the most important tributary of the Teays River was the Marietta River, which, rising in Monroe County, Ohio, and in Tyler County, West Virginia, followed the present course of the Ohio past Marietta and Parkersburg to Little Hocking, thence, leaving the Ohio, it flowed southward past Torch, Coolville, Tupper's Plains, and Chester to Hartford, West Virginia, where it crossed the present valley of the Ohio River. This stream then flowed southwestward across northern Mason County, West Virginia, to Cheshire, Ohio, thence southward along the present valley of the Ohio to Gallipolis where its course was deflected northwestward past Rodney, Rio Grande, Centerville, Clay, Camba, Keystone, Jackson, and Cove to Glade in

¹For drainage changes see U. S. Geol. Survey Professional Paper No. 13. Drainage Modifications in Southeastern Ohio and Adjacent Parts of West Virginia and Kentucky, by W. G. Tipton.

western Jackson County. At this place the Marietta River joined the Teays which at Waverly united with the Portsmouth to form the Chillicothe.

This old system of rivers, including the Chillicothe, Teays, Portsmouth, and Marietta, with their tributaries, drained all of southern Ohio and adjacent parts of West Virginia and Kentucky before the advance of the Illinoian glacier which appears to be the first great ice sheet covering northern and western Ohio and which inaugurated the present system of drainage by obstructing or burying the lower courses of the older system. The barriers produced slack-water conditions, attended with heavy silting, along the old valleys, and forced the impounded waters to seek new passages, the general trends of which were westward instead of northward. Through these changes the Ohio River and its important tributaries began to assume their present forms. In doing this the present streams frequently have cut passages from the headwaters of one old stream to another, now flow in reversed order in the old channels, or occasionally have excavated independent beds across wide areas. The problem of interpretation is quite complex as causes for such modifications are often obscure. The outlet of the new system of drainage was much lower in elevation than that of the old, consequently rejuvenation took place not only along the major streams but also along most of the important tributaries. This resulted in the newly-formed streams eroding their channels far below the level of the old ones, remnants of which are now found as elevated terraces, upland plains, and much dissected, high-level valleys. This cycle therefore included obstruction by glaciation, silting up of the old channels, cutting of new outlets, and excavation, through rejuvenation, of the beds to lower levels. Both the early and late Wisconsin ice sheets caused many important changes within the glaciated area but only minor ones beyond the border of the ice. Streams heading at or within the terminal moraine were filled with thick deposits of outwashed silt, sand, and gravel which also caused silting of the tributaries thus obstructed to corresponding levels. This led eventually to the gradual widening of the valleys through meandering of the streams and to the formation of slender terraces through removal of a part of the filling. Further, minor deflections in the courses of the streams are evident in some localities. Map II shows the general outline of the main drainage system in preglacial time.

On the basis of preglacial drainage, Vinton County may be divided into two districts, the western part which was drained by tributaries of the Chillicothe River, and the eastern part, including about seven-tenths of the entire area, by laterals of the Marietta River. The waters from these basins now go to the Scioto River and to Raccoon Creek respectively. The main divide separating them passes northward through sections 3, 34, 28, 21, 15, 22, 14, 11, 2, and 1, Richland Town-

hip, and sections 36, 35, 26, 23, 13, 14, 11, 2, and 1, Jackson Township. Preglacial drainage east of this watershed was much different from that at present but west of the divide the original system was not greatly altered. Various modifications will be considered in a more specific way.

Salt Creek.—Salt Creek now heads far within the glaciated area in Clear Creek Township, Fairfield County, and flows southeastward past Tarlton, Pickaway County, to Adelphi, Ross County, where it is joined by Laurel Run which rises northeastward in Laurel Township, Hocking County. The valley shows abnormal features which are well described by Tight:¹

“The present valley of Salt Creek at Adelphi is about one mile wide and is very much obstructed with heavy glacial deposits. A view from the cemetery hill at Adelphi towards the northwest and north shows the broad expanse of the outwash apron from the strong morainic ridge of one of the later (Wisconsin) ice invasions. While the deposits of till in the immediate valley at Adelphi seem to be of much earlier (Illinoian) date than the morainic ridge which lies some distance northwest, the headwater streams of Salt Creek above Adelphi are all distributed over the outwash apron and the morainic ridges of the more recent (Wisconsin) glacial deposits. The broad valley formed between the moraine and the Carboniferous hills is described by G. Frederick Wright in his writings on the terminal moraine through Ohio.

“To the southwest extends a long range of Carboniferous hills, over which is a more or less irregular veneering of glacial till; but it is evident that these hills offered effective resistance to the southward movement of the ice, which was not able to surmount them to any large extent.

“To the east the view extends into the mouth of the valley of Laurel Run, which is a rather broad valley bounded by rock walls having very mature contours. The direction of the valley is opposed to that of the present Salt Creek Valley but normal to the restored drainage.

“To the southeast the view is down the valley of Salt Creek, but the features of the valley indicate clearly that the view in that direction is up the stream which was instrumental in shaping the valley, for the valley diminishes in width gradually in this direction and resembles very closely the view which is obtained in looking up the Laurel Run Valley, except that the former is somewhat larger. The till which blocks the valley at Adelphi is accumulated in hillocks rising about 125 feet above the present stream, and it appears as if these deposits had at one time formed a complete barrier across the mouth of the valley, but had more recently been cut through by the action of the stream. The till, where exposed, is of light yellow color and is weathered very deeply, in some places as much as 6 or 8 feet, and contains stones which are very much decayed even when obtained from several feet below the surface. Some sections of the till are bouldery, containing stones of granite, syenite, diorite, and limestone, ranging up to 3 or 4 feet in diameter. Below the weathered zone of yellow till is a light-blue till of undetermined thickness. Many of the contained stones are beautifully striated. In a few places the till shows some stratification, as though it might have been deposited in connection with a body of water.

“Passing down the present stream, or up the old valley, as it were, there appear to be two systems of terraces; an upper set, which corresponds in a general way to the elevation of the till deposits that block the valley at Adelphi and that slope somewhat rapidly as they pass down the stream; and a second set, which lies at a much lower

¹Tight, W. G., Drainage Modifications in Southeastern Ohio and Adjacent Parts of West Virginia and Kentucky, U. S. Geol. Survey Professional Paper No. 13, pp. 19-22.

level and which appears to pass westward beyond the obstructions that block the valley and to be associated with the outwash apron of the outer moraine. These two sets of terraces differ also materially in their structure. The upper terrace is made up largely of very heterogeneous material, in most cases showing considerable water action in the process of its deposition, but in others resembling closely a typical till. These terraces are much more irregular and heterogeneous in structure, and are composed of coarser material, next to the morainic deposits in the mouth of the valley, and increase in the fineness of the material and in the amount of stratification as the distance from the till hills increases. A section about a mile from Adelphi shows, in the upper part, a weathered zone of about 6 feet of finely stratified silt; below this the material is somewhat coarser for about a foot; then comes a large lenticular mass of very coarse material about 4 feet in maximum thickness, embedded in a 15 or 20 foot bed of very fine sand; below this is a very regular belt of well-washed gravel about 2 feet thick; and below that about 20 feet of very coarse materials, showing very little stratification and yet evidently waterlaid. Scattered somewhat irregularly through the whole deposit—peppered in, as it were—are numerous stones and bowlders, a few as much as 3 feet in diameter. Some sections a little farther down the valley showed a deposit of 30 to 40 feet, composed almost entirely of very fine silt. At Haynes the valley is less than three-quarters of a mile in width, and the upper terrace deposits in this vicinity are composed entirely of fine silts and sand. In a few cases the sand is so coarse that it might almost be classed as gravel, and is as well sorted as if it had been run through a sieve. While the upper terraces are extensively preserved in the portion of the valley near Adelphi, down the stream they have been more largely removed, and in the vicinity of Haynes almost the last indication of them may be noted in a group of sand hills north of the village, almost in the mouth of the valley of a tributary creek (Pine Creek). From the nature of this material it is easy to understand how the valley has been swept almost entirely free of the deposits. These sand hills near Haynes are very interesting remnants of the old terrace, as they have slopes of about 25 degrees and are conical in form, rising one above the other in a progressive series to an elevation of about 200 feet above the valley floor. Below Haynes scarcely a remnant of these deposits was observed.

"The terraces of the second or lower series are composed almost uniformly of well-washed coarse gravel. They slope down the stream, the material of the terrace becoming considerably finer and the terraces themselves entirely disappearing a short distance below Haynes.

"A few miles below Haynes, Salt Creek turns abruptly southwestward, while the valley continues eastward, growing rapidly smaller to South Bloomingville and beyond. In this section of the valley there are deep silt deposits, which are very finely laminated, showing their deposition in slack water. These silts are leached to a great depth, so that they show no acid reaction at least 10 feet below the surface. Their material seems to be entirely of local origin, being the outwash from the neighboring Carboniferous shales and sandstones. At the point where this tributary joins Salt Creek the two valleys are about a quarter of a mile in width. From this point down stream the valley of Salt Creek gets rapidly narrower and its walls become steeper and more precipitous until it reaches its minimum width near the Pine Cottage School in Section 36, Salt Creek Township, Hocking County, where it is a veritable gorge. Below this place it broadens again to Eagle Mills where it unites with a tributary (Pretty Run) of about similar size which comes in from the east. From Eagle Mills the north fork of the valley widens gradually downstream. Its floor is deeply covered with gravel deposits in the form of high terraces. Just at the place where the stream emerges from the gorge, near the Lebanon M. E. church at the mouth of Pretty Run, these terraces are about 25 feet above the present stream; they are composed of well-rounded gravel, all of which has undoubtedly been washed from the original deposits in the upper section of Salt Creek Valley through the gorge. From the characters of the valley from Adelphi to the gorge near the Vinton County line and of the tributaries, it seems certain that in

preglacial times there was a col in the old divide at the Pine Cottage School in Section 36, Salt Creek Township, Hocking County, and that the drainage of the section of the valley north of this col was the reverse of that of present Salt Creek. The nature of the deposits in the upper portion of this valley, around Adelphi and to the northwest, would seem to indicate that at the time of the maximum advance of the ice its front stood across the valley at Adelphi and offered a complete obstruction to the northwestward discharge of Adelphi Creek, thus impounding the waters until they rose over the col at the Pine Cottage School. Into these waters were discharged the great burden of glacial debris which formed the upper terraces. The coarser materials would naturally be deposited nearest the front of the ice, and the material would be finer farther down the stream. In the portion of the valley beyond the main current—that is, beyond the point where the present stream turns to the southwest—the waters were almost quiet, except for the slight currents produced by the small tributaries, and in these quiet waters the heavy deposits of silt were laid down. As the col at the Pine Cottage School was worn away, the flood waters from the ice removed *pari passu* the terraces previously deposited, but on account of the smaller volume of water in these small tributaries the silts in the blind end of the valley were not so completely removed. It would seem that this stage was followed by a recession of the ice from its position at Adelphi which would probably mean a cessation of the supply of material, but, at least for a time, a continuation of the flood waters. Following this there must have been a readvance of the ice, or, what seems more certain, the advance of ice of another epoch, which reached the position of the outer moraine northwest of Adelphi. The outwash apron from this moraine extends to the deposits at Adelphi and passes down the valley of Salt Creek as a gravel train; but these gravels which form the lower series of terraces, did not rise nearly to the height of the older series. After the deposition of these terraces the supply of material was stopped, while the flood waters continued, and the deposits were worn out to the level of the present stream or nearly so. Since the falling off of the glacial floods the present stream seems to have accomplished little but the meandering of its course over the valley floor, with a certain amount of silting of its flood plain, as the stream is now on rock bottom, or nearly so, in the gorge at the col at Pine Cottage School. A comparison of the deposits in the mouth of the old valley at Adelphi and the neighboring moraine beyond the apron would indicate a great difference in the age of the two moraines, and would suggest that the modifications of drainage in the Salt Creek Basin and the reversal of the old Adelphi Creek were accomplished at the time of the earliest ice invasion of the region. This may be correlated with the Illinoian of the western region, and possibly with the Kansan, while the outer moraine would seem to belong to the Wisconsin."

The col near Pine Cottage School in Section 36, Salt Creek Township, Hocking County, is one of the most definite in this part of the State as is shown by the trend of dividing ridges, the gorge-like character of the valley, direction of flow and size of the tributaries of Salt Creek in this locality, widening of the valley both to the north and to the south from this place. South of the col Salt Creek with its tributaries, Pike and Pretty runs, forms a basin which is normal in every respect and in harmony with others in the general region.

Southwestward from Eagle Mills to the Vinton-Ross county line the valley of Salt Creek is, on the average, nearly one-half mile in width and is quite uniform throughout. Terraces are not conspicuous except small ones on the flood plains. In Section 31, Eagle Township, Salt Creek is joined by Pike Run which rises in southwestern Salt

Creek Township, Hocking County, and flows southward in a valley that widens gradually in a downstream direction. The trends of the laterals are also normal to that of the main stream. The most noteworthy features are long finger terraces that project far into the valley in the central parts of sections 20 and 29, and stand from 30 to 70 feet above the flood plains. These are composed of rock with a covering of fine sandy silts and soapy clays, both highly weathered. They represent the floor of the stream that flowed in this valley in preglacial time. These remnants are parts of the old floor that escaped destruction through the rejuvenation of the stream by the reversal of the drainage which lowered the outlet.

A modification of Salt Creek of note is the abrupt deflection of the course from southwestward to southward in Section 12, Liberty Township, Ross County. The preglacial stream that occupied Salt Creek Valley here continued on southwestward through the broad plain in Section 11 to where it joined the major stream, Chillicothe River, just north of Londonderry. The floor of the old stream in Section 11 is overlain by clays and silts, normal deposits for the beds, and, above these, by fine sand and gravel, outwash from the Illinoian glacier. The cause for the change of drainage is quite evident as this early ice sheet completely blocked the outlet, which was the Chillicothe River, about 3 miles west of Londonderry. Waters from the Salt Creek Basin were thus compelled to find a new outlet, which they did, by turning south in Section 12 and excavating a channel through a projection of the highland area. This appears to have been accomplished by crossing a low divide between a tributary of old Salt Creek and another of the Chillicothe River. The position of the col is indicated near Point Lookout by the tortuous course of the present stream, the abruptness of the walls and the absence of terraces and silts thereon, the presence of bedrock through this part of the course, and the direction of the main dividing ridge. From this place the new course of Salt Creek was along the eastern margin of the old Chillicothe Valley to the Scioto River near Richmondale.

Middle Fork of Salt Creek.—The Middle Fork of Salt Creek rises near the village of Stella in northeastern Jackson Township, flows southwestward past Allensville, Richland Township, and Ratcliffburg, Harrison Township, to Section 21, thence southward to Section 33, and thence westward to West Junction, Section 36, Jefferson Township, Ross County, where it unites with Salt Creek. That part of the basin above Allensville is normal in every respect and the streams in it were little affected by the general reversal of drainage except that their channels were deepened somewhat, thus making them more active. The main valley widens gradually in a downstream direction and the laterals enter at the proper angle.

Riley Run, a tributary entering the main stream at Allensville and flowing from the southeast, shows some modifications near its headwaters. The divide of the old stream appears to have been near the northern part of Section 15, Richland Township, whereas that of the present one is just south of the Wyckoff Crossroads in Section 22. The valley at the latter place is evidently an old stream bed rather than a divide eroded to such a low level, as it is filled with highly leached sand and gravel and continues, well-defined, on southward past the Darby School to Little Raccoon Creek. This shifting of the divide was occasioned by the west-flowing stream being more active than the east-flowing one.

Along Middle Fork west of Allensville the first feature of note is the high terrace just east of the Persimmon School in central Section 7, Richland Township. This is a remnant of the floor of the preglacial stream as is indicated by its elevation and by the character of sediments upon the bedrock. From the Persimmon School these terraces and flats of the preglacial stream continue southwestward through the southwestern part of Section 7, Richland Township, and thence northwestward through southeastern Section 12, Harrison Township. The old stream made a wide bend here whereas the present one continues on straight westward, thus leaving an isolated hill between the two courses. The rock floor in the old valley south of this hill has an elevation of about 700 feet and is overlain by 30 feet or more of highly leached deposits. Next to the rock is a layer of sand with much flint from the upper Pottsville and lower Allegheny beds to the east. This is overlain by sands and sandy silts above which is present the fine-grained, soapy silts deposited during the slack-water stage when these valleys were finger lakes. Through the rejuvenation following the reversal of drainage the stream took the more direct course from central Section 12, Harrison Township, to central Section 7, Richland. The present valley here is about normal in width but is somewhat youthful in appearance as it has rather steep walls and is not bordered by terraces.

A remnant of the old floor in the form of a long finger terrace projecting far into the valley is well preserved in western Section 12, Harrison Township. It stands about 60 feet above the flood plain and has steep walls with a flat top. It is composed of rock the upper surface of which has an elevation of about 680 feet. The silts upon this terrace are of the type characteristic of old drainage lines.

From Ratcliffburg in Section 11, Harrison Township, the preglacial stream that drained the basin of Middle Fork flowed southwestward across central Section 15, southeastern Section 16, and northwestern Section 21, thence westward across the central parts of sections 20 and 19 to Section 24, Liberty Township, Ross County, where it united with the major stream, the Chillicothe River. The old course is well defined throughout the entire way and is heavily silted with

fine sands and soapy clays. The rock floor shows a low gradient towards the west. At Ratcliffburg the present stream did not follow the old valley but by tortuous meanders it passes around an isolated hill, formerly connected to the main ridge to the east. The deflection here was probably due to the influence of small tributary streams and to heavy silting which raised the waters above low divides. Similar features are also present in Section 21, where Middle Fork has excavated a new channel through a projection of the highland area, thus leaving a conical hill standing far out in the valley.

The course of Middle Fork from the central part of Section 21, Harrison Township, is southward across Section 28 to central Section 33, through a valley that is rather tortuous in outline but about normal in width. The walls, however, are steep and little dissected, indicating the youthfulness of the excavation. Further, the silt terraces are low and the materials composing them are not highly leached. No col is sharply defined but projections from the main ridges indicate that a low divide was formerly present in central Section 28. All the features tend to show that this part of the course is new, or that it was cut during the reversal of the drainage caused by the Illinoian glacier.

Middle Fork, at its junction with Pigeon Creek in Section 33, Harrison Township, makes a direct turn of more than 90 degrees and then flows westward to Section 36, Jefferson Township, Ross County, where it unites with Salt Creek. In this part of the course the valley is much below normal in width as it averages only about half what it does farther upstream. The size of the valley and the direction of the course are more in accord with that of Pigeon Creek on eastward past Ray to Byer. During the drainage changes, Middle Fork thus appears to have cut a new channel from its old course in Section 21, Harrison Township, to the valley of Pigeon Creek in Section 33, and then to have followed this on westward to Salt Creek near West Junction, Ross County.

Hamden Creek.—The central and northeastern parts of Vinton County were formerly drained by streams the courses of which were much different from those of the present time. Many changes are evident throughout the entire area. Headwaters of the preglacial stream were in Washington and Starr townships, Hocking County. These united near Orland, Vinton County. From here the general course of the stream was southward past Creola, Elk Fork, and McArthur to Dundas, thence southwestward to Hamden, thence southward past Wellston, Roads, and Ridgeland, to Rocky Hill, Jackson County, and thence westward to Keystone, where it united with the preglacial Marietta River. This valley is quite distinct most of the way from Orland to Keystone. As it is especially well defined near

Hamden, the old stream will be named Hamden Creek for ease in description.

The headwaters of Hamden Creek were much the same as those of the present stream, Raccoon Creek, that is, it received the waters from the basin in Washington and Starr townships, Hocking County, now drained by East Branch Honey Fork and West Branch. Some deviation is found between preglacial and present streams. East Branch formerly flowed westward from Starr over the low, heavily silted divide at New Plymouth to Orland, where it united with West Branch. The outlying hill at New Plymouth is another example of slight shifting of course common to these preglacial valleys. The changes along West Branch are not conspicuous, except that the present stream flows up what was the former course of East Branch from Orland to New Plymouth. This preglacial stage of drainage is represented by deposits of highly leached silts and clays locally present along the borders of the valley. Such accumulations occur mainly between elevations of 790 and 830 feet.

At present the East Branch and West Branch unite south of New Plymouth to form Raccoon Creek. This stream for about 2 miles flows southward through a valley which is locally constricted, and has rather steep and little dissected walls. This section of the course, compared to that elsewhere, shows immaturity or that it is not a part of the original drainage. From narrowness of the valley, abruptness of the walls, absence of silts, and trend of the main ridges, a col is indicated near the southern line of Section 36, Brown Township. Waters in this basin were formerly discharged southward from Orland over the low divide in Section 11, Swan Township, to Brushy Fork. In this abandoned valley the rock floor has an elevation of about 795 feet and is overlain by nearly 40 feet of silt, which locally, however, has been partially removed by erosion. In these deposits the lower layers are fine in texture, sandy in character, and yellow to gray in color. Above these are present highly laminated clays which are soapy and plastic and vary from yellow to bluish-gray. All the materials are highly leached. Along this part of the course the adjacent hills are low, well rounded, and maturely dissected. From Section 11, Swan Township, the Hamden Valley is clearly defined and widens gradually to Creola. The tributaries are normal in position and in direction of flow. Rock shoulders, remnants of the old floor with highly leached silt deposition upon them, are present at a number of places along the valley.

Drainage modifications are apparent at Creola where Brushy Fork changes its course from southward to eastward and flows with many flexures in a valley the features of which indicate a col in the central part of Section 34, Swan Township. Hamden Creek, the preglacial stream, continued on southward from Creola to Elk Fork. The old

valley is well preserved. The floor has an elevation of about 760 feet and is overlain by thick deposits of sandy silts and finely laminated clays, the upper limit of which is about 830 feet above tide. In central Section 4, Elk Township, Hamden Creek received a tributary from the west. The old valley has been little disturbed and is therefore choked with deposits of silt and clay, characteristics of the older streams. The original stream drained what is now the headwaters of Elk Fork which shifted its course from this tributary of Hamden Creek to the one south in southwestern Section 5 and northwestern Section 8. This part of the valley is youthful in appearance compared to that elsewhere.

At Elk Fork, Hamden Creek received a rather large tributary from the east, the course of which is well defined most of the way. This stream rose near the Hocking county line in north central Brown Township, flowed southwestward down Twomile Run, thence down Raccoon Creek to Section 35, Swan Township, and thence over the wide flats in Section 3, Elk Township, to the village of Elk Fork where it united with the major stream. The valley of Twomile Run and that of Raccoon Creek widen gradually to Section 35 and the streams receive their laterals in the proper direction. The gradient of the old floor and also of the silt deposits is to the southwest or in the direction of flow. The first modification of special note is the sharp deflection of Raccoon Creek in Section 35, Swan Township, from southwestward to southeastward. Through sections 2, 1, and 12, Elk Township, this stream flows in a valley which has steep and little-dissected walls, is below normal in width, and is free from deposits of silts of the highly leached type. From these features and from the position of the main water divides, a col is evident in central Section 2, Elk Township. Its location here is further strengthened by the average length of tributaries received from the northwest compared to those from the southeast. The former flowing down the dip of the rocks are always longer than those flowing against the dip. The evidence thus favors the theory that the preglacial stream flowed on southwestward from Section 35, Brown Township, to the village of Elk Fork where it joined Hamden Creek. The valley through this area is clearly defined and its width is in accord with that farther upstream. On the wide flats in Section 3, Elk Township, the rock floor has an elevation not far from 750 feet and is heavily covered with sandy silts and soapy clays of the older drainage phase. This tributary of Hamden Creek had a length of more than 10 miles and drained an area of nearly 18 square miles.

The broad expanse of valley from the village of Elk Fork southward past McArthur to Dundas clearly defines the course of the preglacial stream, Hamden Creek. In this valley, where it has been little disturbed just north of McArthur, the rock floor has an elevation of about 735 feet and is overlain by 15 to 20 feet of silt, which is fine in texture, yellow to gray in color, and siliceous in character. In the basal portion

many pieces of much weathered flint are present. The upper limit of the highly laminated, soapy clays is close to 830 feet. This valley all the way from Elk Fork to Dundas is well filled with such material. The changes along the present streams, Elk Fork and Puncheon Fork, are worthy of attention. Elk Fork enters the Hamden Valley from the northwest in Section 16, Elk Township, and is then deflected south-eastward through a tortuous course to Section 26, where it again crosses another abandoned valley. Most of this part of the valley is youthful in appearance. Its erosion probably commenced during the slack-water stage when the circulation was deflected over low divides separating tributary streams. At that time the water in the old valley at McArthur stood above the 830 foot contour as the fine, laminated silts extend to this level. Cols are indicated in the northwest corner of Section 22, Elk Township, and in north central Section 27. Puncheon Fork rises in Section 36, Jackson Township, flows southeastward past McArthur, and joins Elk Fork in Section 22, Elk Township. The pre-glacial stream rose in the same highlands but flowed southeastward diagonally across sections 18, 20, and 21 to McArthur. The Chilliscothe-McArthur road now follows this old drainage way which is deeply filled with silts and clays to an elevation of 830 feet or more. Instead of following the old course, the present stream, migrating southward with the dip of the rocks, cut a new channel from one minor tributary to another. The presence of soft sandstones in bedrock aided in the work.

Zaleski Creek.—Near Dundas, Hamden Creek received from the northeast an important tributary which for convenience in describing and on account of its prominence near Zaleski is designated Zaleski Creek. The headwaters of this old stream were those of Sandy Run in northeastern Brown Township. Its general course was southwestward past Hope Furnace, Zaleski, and Vinton to Dundas where it joined the major stream. A number of noteworthy features are found along Zaleski Creek. Passing down Sandy Run from its headwaters, the valley is normal in appearance and in arrangement of laterals to Hope Furnace, where it makes a wide bow before continuing on in the same general direction. From Hope Furnace, Zaleski Creek passed on southwestward over the low divide whereas the present stream cut a new channel from one old tributary to another. The rock floor on this divide has an elevation of 780 feet and is overlain by stream-deposited material. Well preserved terraces at an elevation of 750 to 770 feet are present along Sandy Run near its mouth and along Raccoon Creek south of this. At Hope, the old stream was joined by a tributary from the east which rose near Moonville. One col, since eroded by Raccoon Creek, was in central Section 7, Brown Township, and another on Hewett Fork was located in northwestern Section 7. From Hope to Zaleski, the valley is quite wide through the united efforts of old Zaleski

Creek and of the present stream, Raccoon Creek, which flows in a reversed direction to that of the preglacial one. On the high terrace, Brewer Cut, that projects far into the valley in Section 19, Brown Township, the floor of Zaleski Creek is well preserved. The bedrock has an elevation of about 760 feet and is overlain by silts the basal portion of which contains much flint, highly bleached. The floor of this old stream with an elevation of 750 feet is again sharply defined by the high terrace which has been little disturbed and on which the village of Zaleski stands. The deposits here are of the usual kind, sand and silt with flint, sandy silt, and fine-grained clay. Along the wall of the valley stream-lain material is present to about the 800-foot contour.

Wheelabout Creek, a tributary of Raccoon entering at Zaleski, has also undergone modifications due to the change in drainage. It rises in northeastern Madison Township, flows southwestward for a few miles, then turns abruptly northwestward, and continues through a narrow valley with abrupt and little dissected walls. The general features indicate the position of a col in south central Section 29, Madison Township. The course of the preglacial stream is easily followed southwestward to Prattsville, thence westward to Zaleski Creek in Section 25, Elk Township. This valley widens gradually in a downstream direction and is heavily silted most of the way with material derived from near-by sources. Where the old floor is little disturbed, as at Prattsville and on the low divide in the northwestern corner of Section 32, the elevations of the bedrock are not far from 760 and 750 feet respectively.

From Zaleski to Dundas the course of the preglacial stream, Zaleski Creek, was along the line now followed by the Baltimore and Ohio Southwestern Railroad. The old valley is clearly defined as most of it has been little disturbed since the change causing abandonment. Thick deposits of stream-lain material, consisting of silt, sand, and flint, are present in sections 13, 23, 24, 26, 35, and 34, Elk Township. Overlying these are present locally the highly laminated clays of the slack-water stage. Many changes are evident. Elk Fork now crosses the old valley at nearly right angles in Section 26, Elk Township. Its course is along a western tributary from the col in the north central part of Section 27 to the main valley and then reversed along an eastern tributary through the col in southwestern Section 19, Madison Township, to another basin. Wolf Run, rising in the old valleys near Dundas, has excavated a new and tortuous channel across sections 35 and 36, Elk Township, to Vinton Furnace, where it unites with Elk Fork. From Dundas, Hamden Creek flowed southwestward to Hamden, thence southward past Wellston, Roads, and Ridgeland to Rocky Hill, and thence westward to Keystone, where it united with the old Marietta River. The rock floor gradually descends in the downstream direction and the old valley is heavily silted all the way.

Only minor changes are evident in the headwaters of Little Raccoon Creek north of Hamden, but the course of the main stream from this village southeastward across Jackson County to Vinton, Gallia County, is largely postglacial. Its channel has been eroded across the headwaters of several small tributaries of the older system.

Wilkesville Creek.—In preglacial time southeastern Vinton, western Meigs, and northwestern Gallia counties were drained by a stream which rose near Carpenter, in Columbia and Scipio townships, Meigs County, and flowed southwestward past Wilkesville, Vinton County, and Ewington, Vinton, and Harrisburg, Gallia County, to Rio Grande, where it joined the major stream, the Marietta River. As the old valley is exceptionally well preserved near Wilkesville, this tributary of the Marietta River is called Wilkesville Creek.

In the vicinity of Carpenter remnants of terraces on Leading Creek and Fivemile Run which were the headwaters of Wilkesville Creek indicate that the rock floor of the old stream has an elevation of nearly 720 feet. The valley, however, is best seen in southeastern Section 16, Columbia Township, where it has been little disturbed by recent erosive agencies. At this place the rock floor with an elevation of about 710 feet is directly overlain by a few feet of brown to yellow sand with gravel and pieces of bleached flint. Superimposed on this deposit are thick beds of sands and silts which vary in color from dark brown to light yellow and in texture from very fine to medium coarse. Locally these beds are 20 to 40 feet thick. The upper limit of such deposits along the valley walls is at an elevation of 760 feet. Wilkesville Creek from Section 16, Columbia Township, flowed southward across southeastern Section 21 and the central parts of sections 20 and 19 to northern Section 24, Salem Township. In this old valley in the south central part of Section 21 the following record was obtained:

	Ft.	In.
Covered.		
Silt, sand, and covered.....	23	0
Sand, brownish-red, with some gravel.....	4	0
Sand, dark, with gravel and flint.....	10	0
Valley floor, elevation 688 feet.		
Sandstone, bedrock.....	20	0

The elevation of the floor in this part of the valley thus appears to be about 690 feet above tide. The deposits are molding sand types which are so characteristic of these old valleys. South of this in sections 20 and 19, along the tributary of Ogden Run, the old gradation plains are quite well defined by remnants of terraces along the valley walls. Similar features are present in southwestern Section 19 where the old floor has an elevation of nearly 700 feet and is overlain by 15 feet or more of rather coarse, reddish-brown sand. At this

place Wilkesville Creek was joined by a tributary which rose near the Cottrill School in Section 12, Vinton Township, Vinton County, and flowed southeastward past the villages of Vales Mills and Point Rock to Section 24, Salem Township, Meigs County. Raccoon Creek crosses this old valley at Vales Mills. On the low divide in the central part of Section 34, Columbia Township, Meigs County, the rock floor of the old stream has an elevation of about 745 feet, and is overlain by 20 feet or more of sandy silts. No deposits of slack-water clays were observed. The valley is narrow, indicating that it was occupied by only a small stream. It is in keeping with that of the tributary entering Raccoon Creek at Vales Mills. At Point Rock the old valley is rather wide and flat and has been little modified by recent erosive agencies. Exposures indicate that the bedrock has an elevation of about 725 feet and that the valley was filled with nearly 40 feet of sediments. The basal deposits are sands and sandy silts and the upper layers are soapy clays of slack-water stage. The gradient of the floor, the size of the valley, and the character of the sediments indicate that this was a tributary of Wilkesville Creek heading in the main water divide between this basin and that of Hamden Creek.

From Section 24, Salem Township, Wilkesville Creek flowed southward to Dexter Run in Section 23, thence southwestward across sections 29 and 34 to Wilkesville. The low plain in southeastern Section 24 shows the characteristic fluvial deposits. The rock floor was not exposed but a thin stratum of gravel, sand, and flint is present at an elevation of nearly 690 feet, thus indicating its presence only a few feet below. This basal stratum is overlain by 30 to 40 feet of fine-grained, ferruginous sands and silts. Similar deposits are present but poorly exposed in southern Section 29. In the vicinity of Wilkesville the old gradation plain is clearly defined as it has been little dissected by the present streams. The elevation of the floor is not far from 690 feet and that of the top of the plastic, highly laminated silts of the slack-water stage, found now only along the walls of the valley, is 750 feet. Exposures indicate that the thickness of this bed was at least 20 feet. The deposits between the rock floor and these slack-water clays consist of ferruginous sands and silts of various degrees of fineness. In general they are rather highly leached.

At Wilkesville the main stream received a tributary from the east and another from the northwest. The headwaters of the latter appear to have been at the main water divide in southeastern Madison Township. From Section 24, Vinton Township, the course of the stream was southeastward along that of the present stream, Elk Fork, to Raccoon Creek, thence along this across Section 15, to where it left the present valley in northeastern Section 14. From this place the gradation plain is quite distinct across sections 8 and 7, Vinton Township, and 12, 11, 5, and 4, Wilkesville Township. Along Elk Fork little evi-

dence of the old floor is now apparent but near the mouth of this stream and along Raccoon Creek rock terraces, highly silted, are present at an elevation of 720 feet. The following record taken in northeastern Section 14, Vinton Township, shows the character of the deposits lying on the bedrock:

	Ft.	In.
Sand, silty, ferruginous.....	15	0
Sand, with gravel and flint.....	7	0
Rock floor, elevation 720 feet.		
Sandstone, <i>Allegheny</i>	20	0

On the low divide in southeastern Section 12, Wilkesville Township, and on that in eastern Section 11, the rock floor has an elevation of nearly 700 feet and the highest silts have an elevation of nearly 750 feet. This preglacial stream evidently flowed southward as the valley widens perceptibly and the floor level decreases in that direction. Further, the tributaries enter at an appropriate angle for such a course.

From Wilkesville the course of the preglacial stream, Wilkesville Creek, was southward across the western parts of sections 3 and 2, thence westward to Raccoon Creek, thence southward along this valley past Ewington, Vinton, and Harrisburg to Rio Grande, where it joined the Marietta River. The gradation plains are only locally well preserved as the present streams have obliterated much of the old valley. They have left, however, a sufficient number of silt-covered terraces so that the route may be traced with confidence. Such remnants are present in southwestern Section 3, Wilkesville Township, and in western Section 2. The following record taken on the plain in southwestern Section 2 shows the general character of the alluvial deposits in this locality and the elevation of the rock floor:

	Ft.	In.
Sand, mostly fine, parts argillaceous.....	20	0
Sand, with gravel and flint.....	5	0
Floor level, elevation 685 feet.		
Sandstone, <i>Conemaugh</i>	5	0

Locally these argillaceous sands are overlain with 10 to 20 feet of fine, highly laminated clay, representing the slack-water stage. The upper limit of this material appears to be about 720 feet above tide. Near Ewington in Gallia County the old valley is well defined by the high flats and terraces present locally along Raccoon Creek. The deposits upon them consist of brown and yellow sands and leached silts which are so characteristic of these preglacial valleys elsewhere. The elevation of the floor is nearly 670 feet. From Ewington to Rio Grande the general features are not especially different except through modifications by the present stream, Raccoon Creek. From Carpenter to Rio Grande the gradient of Wilkesville Creek is nearly 2 feet per mile as the rock floor in this distance of about 27 miles descends from 720

to 665 feet above tide. The deposits within the valley are similar throughout the entire way. The bedrock is directly overlain by a few feet of sand, containing more or less gravel and flint. The gravel is locally derived as it consists mainly of ferruginous shale and sandstone. The flint is also from near-by sources as the adjacent hills contain the Brush Creek limestone which is decidedly flinty in most of the basin drained. Superimposed on this stratum are thick deposits of sand, varying in texture from fine to coarse and in color from light yellow to dark brown. The coarser grained sands are loosely bonded with iron oxide which forms a thick, rusty coating on the grains. In those of finer texture argillaceous material is also abundant. These sands are very similar to the molding sand worked near Kerr and Evergreen in Gallia County. The highest deposits in these old valleys are slack-water clays which are fine grained, exceedingly plastic, and highly laminated. The color varies from light gray to blue, depending on the state of weathering. Such deposits are most abundant along the borders of the valley where the old gradation plain has been little disturbed. In Vinton County Wilkesville Creek drained small areas in southeastern Madison and southern Knox townships and nearly all of Vinton and Wilkesville townships. The preglacial drainage in Knox Township and in the eastern part of Brown was eastward into Athens County to streams the valleys of which are quite prominent near Albany and Athens. The direction of the main stream, however, has not as yet been definitely determined.

SURFACE FEATURES

Peneplains and old valley floors

All of southern and eastern Ohio is hilly and rough due to degrading agencies that have been operative since these rocks were re-elevated at about the close of Cretaceous time. The upwarping, however, did not progress at a uniform rate. Periods of uplift were followed by periods of quiescence. The movement at any time was not great, that is, it was sufficient to raise the surface only a short distance. During a long period of repose, erosive forces were able to reduce the land to a relatively low, almost featureless surface, known as a peneplain. If another cycle of elevation and erosion occurred, a second peneplain would be produced at a lower level with partial or total obliteration of the older one. Such surfaces are independent of rock structure as they may extend across many formations. Most of the cycles were not complete, leaving remnants of the preceding peneplains. A wide valley resulting from stream action is known as a strath.

One of the marked surface features of Vinton County and also of adjacent areas is the rather even elevation of the crests of the high

ridges along the main watersheds and the presence of conspicuous terraces and flats, at lower levels, on most of the lateral ridges. Such modifications apparently resulted from the process of denudation at different periods. The physiographic history of the region, however, is far from clear definition as many original surface features have been partially or almost completely obliterated.

Near the close of the Paleozoic era, crustal movements resulted in the uplifting of the Appalachian Mountains and also in the emergence above sea of most areas bordering these highlands. During the Mesozoic era that followed this upwarping, these land areas were so eroded that they were reduced to a plain which was later uplifted and which is now represented by the plateau surface flanking these mountains. Succeeding this, other cycles of uplift and erosion produced peneplains and straths at lower levels of which the Harrisburg peneplain, Worthington peneplain, and Parker strath are the most prominent in eastern and southern Ohio.

Harrisburg peneplain.—In Vinton County and in adjacent areas the main ridges along the water divides rise to a rather uniform height, the mean of which is not far from 1,060 feet. The variation, however, is quite wide but it is commonly between 1,020 and 1,100 feet. This level appears to mark a peneplain surface which has been reduced to a very fragmental condition by subsequent erosion and which rises gradually eastward in Ohio to the position of the Harrisburg peneplain of Pennsylvania. The evidence indicates that it was formed by an upwarping of strata in early Tertiary time.

The Harrisburg peneplain in Vinton County is best preserved in the western part but scattered remnants are also present in the eastern part. In Wilkesville, Vinton, Clinton, central Elk, and southern Knox townships, erosion has removed nearly all the evidence of this upper peneplain surface. The area appears to be a part of a low basin which extends on southward through Gallia, Meigs, Lawrence, and eastern Scioto counties. The knobs on the main ridges rise to a rather uniform elevation of about 1,030 feet in northwestern Knox Township and to 1,030 to 1,070 feet in northern and northwestern Madison. The position of the old gradation plain is more apparent in Brown Township. Here the crests of the dividing ridges rise to an elevation of 1,030 to 1,050 feet between Hewett Fork and Sandy Run, to 1,030 to 1,070 feet between Sandy Run and Twomile Run, and to 1,020 to 1,040 feet between Twomile Run and East Branch. The surface in most of Elk Township has been reduced considerably below the level of this old gradation plain. The parts that nearest approach it are the isolated knobs, 1,000 to 1,050 feet in height, in the northeastern part of the area in sections 1, 2, and 11, and in the western part in sections 7, 8, 18, and 19. In the eastern half of Swan Town-

ship the remnants are also few and none rise to an elevation of more than 1,040 feet. The conditions are different, however, in the western part of this township for here most of the main ridges stand above 1,020 feet and many knobs on them reach 1,050 to 1,090 feet. The position of the ancient peneplain surface appears to be well indicated over most of Richland Township where the projections on the ridges rise rather uniformly to 1,020 and 1,070 feet. On account of the location at the head of important drainage basins, the highlands of Jackson Township rather definitely mark the position of the old Harrisburg peneplain as the ridges rise to a rather uniform height throughout the entire area. Along the main divide which deflects the waters eastward to Raccoon Creek and westward to Salt Creek and which extends in a north-south direction across the eastern part of the township, the gradation surface falls between 1,050 and 1,100 feet. No broad uplands are present at this position but many flattened knobs are found not only on the main ridge but also on the laterals. The same is true on the divide between Pretty Run and Queer Creek in the northwestern part of the area and on that between Pretty Run and Middle Fork in the southwestern part. The highlands in most of Harrison Township have been rather severely eroded but the main ridges dividing the larger streams still show remnants of a gradation plain between 1,030 and 1,100 feet. In Eagle Township the Harrisburg peneplain is rather prominent at the position of 1,050 to 1,100 feet above tide on all the main ridges and also on their laterals.

The constant repetition of the summits of the ridges in most of Vinton County rising to a rather uniform elevation between 1,020 and 1,100 feet with a mean approximating 1,060 feet is strong evidence of a peneplain surface at this position. When viewed from a high elevation, the regularity is striking, being repeated in one ridge after another. In all, several hundred swells on the ridges in this county alone project upward to these elevations. This old gradation plain, which is the work of a cycle of slight uplift with extensive erosion, is apparently somewhat uneven in that it slopes gently from the main water divides towards the interiors of the larger drainage basins. The variation, which is perfectly normal for stream-cut surfaces, can not be accurately measured but is probably less than 100 feet. Further, the watersheds were lowered so that little remains of the original plateau surface except in widely isolated areas where bold knobs and ridges stand out as monadnocks on the gradation plain. As has been stated previously, this peneplain apparently correlates with the Harrisburg of Pennsylvania and rises gradually in that direction from an elevation of 1,060 feet in Vinton County to 1,270 feet in Columbiana County, Ohio, to 1,400 feet in Armstrong County, Pennsylvania, to 2,200 feet in Potter County, Pennsylvania, which is the dome of greatest uplift.

In widely separated areas in southern and also in eastern Ohio are found isolated knobs and ridges that rise sharply from 130 to 200 feet or more above the Harrisburg peneplain. In southern Ohio such protuberances are present in the highlands just east of Chillicothe and in several localities in the hilly country west of the Scioto River in Ross, Pike, Scioto, and Adams counties. Whether these represent remnants of an older peneplain or of the original plateau surface has as yet not been determined.

Worthington peneplain. — In late Tertiary time the land which had been reduced during the Harrisburg peneplanation stage to an almost featureless surface not far above sea was again slowly uplifted about 100 feet before the action halted. During the upwarping the streams with renewed activities soon cut deep valleys in the former surface and during the long period of crustal quiescence that followed they gradually developed wide gradation plains along their courses and also reduced the water divides between many basins to much lower levels. This cycle of uplift and erosion resulted in the development of what is known in Pennsylvania as the Worthington peneplain. It is far less complete than the older Harrisburg as it left many remnants of the latter over wide areas. In Vinton County the Worthington peneplain stands at an elevation averaging nearly 960 feet above tide. The position of the old surface is nearly 990 feet near divides and about 930 feet near the central portions of the larger basins. In western Vinton County the peneplanation during the Worthington stage produced simply broad valleys in the Harrisburg surface but in the eastern part it was far more complete, leaving only fragments of the older plain along divides.

In Wilkesville Township the ridges at no place rise above the general level of the Worthington peneplain. The highest part is along the water divide in the western part of the area where the flat ridge crests vary in elevation from 930 to 990 feet. Throughout the central and eastern portions the gradation plain is low as the highest knobs rise to only 880 to 930 feet above tide. This area is well within one of the old preglacial drainage basins. Over most of Knox Township the Worthington surface, 930 to 990 feet in elevation, is well represented and in the northwestern part much-eroded remnants of the older Harrisburg, rising to about 1,030 feet above tide, are also found. The ridge flats in all of Vinton Township are typical Worthington as they have a very uniform elevation not far from 950 feet. In Clinton Township the conditions are similar. Both the Worthington and the Harrisburg peneplains are present in Madison Township, the former appearing most prominent as flats on the long finger ridges projecting from the main highlands. Only a few isolated knobs in northeastern and west central Elk Township project above the general level of the Worthington stage.

In Brown Township the peneplanation in late Tertiary time progressed only to the erosion of broad valleys in the older surface and to a slight lowering of the main divides. The flats and terraces of the Worthington now stand at elevations varying not far from 960 feet and are best preserved on the long lateral hills. The general level of the ridges in eastern Swan Township represents Worthington degradation whereas that along the main water divides in the western part indicates Harrisburg. In Richland Township the high hills alone rise above the more recent stages the plains of which are fairly well preserved at elevations of 930 to 980 feet in the basin of Middle Fork and also that of Little Raccoon Creek. The highlands of Harrison Township are not especially different, both peneplains being evident over most of the area. In Jackson and Eagle townships the streams during Worthington time maturely dissected the old Harrisburg surface and cut broad valleys well towards their headwaters. The main ridges, however, represent older peneplanation. Nearly one-half of the total area of these townships is represented by either one or the other of these gradation plains.

The Worthington cycle of uplift and erosion thus aided perceptibly in the modification of the surface of Vinton County. It was most effective in the southeastern and central portions of the area where the older Harrisburg surface was quite largely destroyed. In the western part of the county the work was less complete, as the period ended before the streams had accomplished more than the development of broad valleys in the higher plain. The upwarping that inaugurated the Worthington cycle of dissection and base leveling was nearly 100 feet. The peneplain thus formed now stands at an elevation not far from 960 feet above tide. It is somewhat higher near the main divides and lower towards the central portions of the larger drainage basins. Later uplifts resulted in the destruction of much of the Worthington peneplain as the rejuvenated streams eroded new valleys to much lower levels. These peneplains, the Worthington and the Harrisburg, occupy about one-third of the total area of the county and afford much land suitable for farming, grazing, and fruit raising.

Parker strath.—The third well-defined modification of the surface of Vinton County through the work of erosive agencies is the Parker strath which is the name applied collectively to the remnants of old valleys formed by stream action just prior to the ice invasion or in late Tertiary time. This new cycle of erosion was inaugurated by a slow uplifting of the land that brought to a close the long period of quiescence which resulted in the formation of the Worthington peneplain. As a consequence of this upward movement of the surface by internal forces the streams were rejuvenated and began carving valleys in the recently elevated plain. The Parker cycle was short



A.—Old drift, probably Illinoian, at Haynes, at the mouth of Pine Creek, Salt Creek Township, Hocking County.



B.—Valley floor of the old Albany Valley at Wilkesville. Parker Strath stage.

compared to more remote ones but yet it was of sufficient duration for a large amount of work to be done. The streams maturely dissected the older gradation surfaces and lowered many of the water divides; they cut rather broad valleys with moderate slopes 200 to 290 feet below the mean level of the Worthington peneplain. The uplifting appears to have been gradual or at least without prolonged pauses as rock-cut terraces are not conspicuous at any position on the valley walls. The further development of the Parker cycle was arrested by the advance of the great glacier which caused general modifications and rearrangement of drainage systems of the entire region. Subsequent to this event the streams have been busily engaged in eroding valleys to still lower levels.

The Parker strath is well preserved in some parts of Vinton County and is in a very fragmentary condition in other parts. Where the present streams are following closely the courses of preglacial ones, this stage is marked only by isolated, rock-cut terraces along the valley walls. In this case the streams have thus been able not only to de-grade channels to much lower levels but to widen new-formed valleys sufficiently to remove most of the older floors. Such strath remnants are not uncommon features along Salt Creek and its larger tributaries in the western part of the county. In regions where the drainage has been radically changed by reversals, by cut-offs, by deflections along new ways, or by migration down the dip, the old beds are marked by wide terraces, by low, broad flats, and by long, poorly drained valleys such as are found near Wilkesville, Hamden, Dundas, Zaleski, McArthur, Elk Fork, Creola, Orland, and New Plymouth. The main physiographic aspects of the Parker stage have been recorded under old drainage modifications, hence only a brief description of its features need be given here.

Near Wilkesville and to the south along "Yankee Road" the Parker strath is well represented by wide flats and terraces standing about 700 feet above tide. Its position here is 50 to 80 feet above the present valley floor of Flatlick Run and 180 to 220 feet below the general level of the Worthington peneplain. These plains are also distinct east and north of Wilkesville. As the preglacial streams in Knox and Vinton townships were small for the most part and as the erosion subsequent to the drainage changes has been severe, the strath stage in these areas is marked only by isolated, rock-cut terraces along some of the courses and by fragments of narrow, poorly drained valleys, now deserted through shifting of the waters to other passages. The position of these old valleys is commonly between 740 and 760 feet above sea. The village of Zaleski in Madison Township is located on the Parker strath. Its surface here stands at an elevation of about 750 feet, that of the Worthington peneplain at 960 feet, that of the Harrisburg peneplain at 1,060, and that of the floor of the present

stream at 690 feet. The region thus shows four cycles of uplift and erosion each of which left its imprint on the topography. West of Prattsville in sections 26 and 32, Madison Township, a part of an old valley of Parker age is sharply outlined and has been little changed since it was abandoned. In Brown Township the preglacial streams were all small and their courses have been followed closely by the present ones. On this account the strath stage is not especially prominent and is marked only by scattered terraces and by occasional flats from stream meandering.

In Clinton Township the Parker strath is exceptionally well represented by the wide valley extending from Hamden northward to Dundas. Parts of its surface are yet very swampy as the present streams have not been able to thoroughly dissect the old plain. In fact, Little Raccoon Creek is the only one that has effectively removed the silt to a sufficient depth to expose the rock floor. Terraces and flats of this age are also locally present along all the small streams entering the main valley. The work of preglacial streams in Elk Township is yet clearly defined. A strath of the Parker cycle continues northward from Dundas past McArthur and Elk Fork to Creola and another extends northeastward from Dundas along the line of the Baltimore and Ohio Southwestern Railroad to Zaleski. Old valleys of smaller size and little disturbed extend northeastward from the village of Elk Fork to Raccoon Creek in Section 35, Swan Township, westward from Elk Fork across sections 4 and 5 to the headwaters of Elk Fork, and northwestward from McArthur across sections 21, 20, and 18 to the upper course of Puncheon Fork. For the most part these plains have not been greatly disturbed as the present streams instead of following the original courses have excavated new channels along other routes. The floors, however, have been swept rather clean of silts and eroded to a depth of 20 to 40 feet where the present streams now cross the old beds. Elsewhere these valleys are drained by minor tributaries which only locally have found consolidated rock. The strath level stands at elevations of 730 to 750 feet along the larger valleys and at 740 to 800 feet along the laterals. In Swan Township strath features, either projecting terraces or long, narrow flats, are common along the route followed by the Hocking Valley Railway from Creola to New Plymouth. The best preserved part is south of Orland where the old floor is still deeply buried by silt. Along the small valleys in the western part of the area such evidence has been largely removed as the present streams have simply cut deeper in the old courses. Small terraces, however, are evident at many places.

In Salt Creek Basin in western Vinton County, in Jackson, Eagle, Harrison, and Richland townships, the Parker stage of erosion is less well preserved than it is in Raccoon Basin in the central and eastern

parts. The effect of the great glacier was not so much a shifting of the courses, except in a few places, as a lowering of the outlets which thus allowed the streams to erode deeper in old beds. In Jackson Township remnants of the preglacial valley floors are small and poorly defined. Along Pike Run in Eagle Township, sections 20 and 29, the Parker is best represented by slender terraces projecting far into the valley. Along Salt Creek and Pretty Run in this area about all that remains of the old beds are small flats raised 30 to 40 feet above flood plains. These are most prominent near Eagle Mills in Section 22 and east of this in Section 23. In this area the Harrisburg peneplain stands, on the average, at an elevation of 1,060 feet, the Worthington at 960 feet, and the Parker strath at 670 feet. The valley walls rise abruptly from the lower to the intermediate level, then more gradually to the upper one found along the summits of the main ridges. Strath features are not prominent in Richland Township as streams are all small and as drainage was only locally modified by glacial action. Small terraces and flats are present along Little Raccoon Creek in the southeastern part of the area and along Middle Fork in Section 7. In Harrison Township the work of preglacial streams is fragmentarily well preserved in the central and western parts. In readjustment of the drainage old channels were locally abandoned and their beds now stand as high flats from 60 to 80 feet above the present flood plains. Such features are present along the Chillicothe-McArthur Road between Salt Creek and Middle Fork in sections 18, 19, and 20, near the Clark School in sections 16 and 21, and west of Ratcliffburg in sections 10 and 15. The strath floor has an elevation not far from 670 feet and is deeply buried with silt. Small terraces are also present along Middle Fork and Pigeon Creek in the southern part of the township.

The imprint of the Parker cycle of uplift and erosion is thus distinct in most of Vinton County and is exceptionally well preserved locally in the central and southern parts. The uplift was sufficient to allow the larger streams to cut from 250 to 290 feet below the mean level of the old Worthington peneplain. The rate of movement appears to have been uniform and somewhat rapid as the streams were able to erode valleys not beyond maturity and with no well-defined terrace other than that caused by the resistance of hard layers of rock. By a relative estimate of work done the Parker cycle appears to have been short compared to the older ones, yet its duration was far greater than the time that has elapsed since the completion of this and the inauguration of the present succession of uplift and erosion.

The Parker strath has been beneficial in many ways toward the development of Vinton County. The Baltimore and Ohio Southwestern Railroad from Zaleski to beyond Hamden and the Hocking

Valley Railway from New Plymouth to Hamden are located throughout most of these distances on strath plains. Such surfaces furnish a natural grade for public roads many miles of which are thus located in this area. Further, abandoned valleys provide easy passages over what would otherwise be rough barriers between the present streams. These gently rolling terraces and flats, having good drainage and standing some little distance above the flood plains of the present streams, form suitable sites for towns and villages. On the Parker strath in Vinton County are located New Plymouth, Creola; Elk Fork, McArthur, Dundas, Zaleski, Prattsville, Hamden, and Wilkesville. It also furnishes many tracts of comparatively level land which are valuable for farming purposes.

CHAPTER II

THE MISSISSIPPIAN SYSTEM

By J. E. Hyde

THE WAVERLY GROUP

The oldest rocks of Vinton County make up the four western townships. These are conglomerates, sandstones, and shales in layers or beds to a thickness of about 360 feet. They are the upper portion of about 1,000 feet thickness of sandstone and shales, sufficiently alike in character and in the history of their formation that the name Waverly group is applied to the whole. The lower portion of this group is exposed to the westward in Ross and Pike counties.¹

The rock beds appear flat-lying on small outcrops, but in fact they dip very gently to the eastward. As a result, the lower beds which are exposed in Ross and Pike counties lie below the level of all streams in the western part of Vinton County. For the same reason, the whole of the group descends to the eastward and its beds are found underlying the entire central and eastern part of the county, where they are penetrated by all wells of a few hundred feet depth.

These sandstones, conglomerates, and shales of the Waverly group, bed on bed to a total thickness of nearly 1,000 feet, can be grouped into nine distinct members or formations, of which the upper six are exposed in valleys of the western part of the county, while the three lower ones are below stream level, but exposed a few miles farther west.

Each of these members or formations can be followed from hill to hill to the northward and southward, across the county into adjoining counties, over long distances, some of them entirely across the State, others three-fourths of the way from the Ohio River to Lake Erie. This is in keeping with the character of most sedimentary rocks.

Some of these formations change rapidly in character from place to place, so that often within a few miles it is difficult to believe the changes, and the true relationships can be established only by careful tracing of the beds. It is not usual to find in sedimentary rocks, such rapid change in character as is found here, and to understand properly these rocks in Vinton County, it is necessary to know something of how they are related to rocks of the same age in adjoining counties.

¹Hyde, J. E., *The Geology of Camp Sherman Quadrangle*, Geol. Survey Ohio, Bulletin 23, 1921.

The chief changes take place across the four western townships from east, northeast to west, southwest. Farther northeast and north across Hocking and Fairfield counties, even more striking changes are present, requiring to some extent recognition of members not present in Vinton County.

The following table shows the subdivisions of the Waverly, and very briefly their character, in the counties to the northeast and southwest of Vinton County. Only the Cuyahoga formation presents notably great differences. The four western townships of Vinton County lie in the transition zone between these counties and exhibit the passage from the Cuyahoga conglomerate of Hocking County into the shales of Pike County.

Subdivisions of the Waverly in Pike, Hocking, and Fairfield counties

	<i>Eastern Pike County</i>	<i>Hocking and Fairfield counties</i>
Logan formation	Vinton, fine-grained sandstones and shales Allensville, coarse sandstone Byer, fine-grained sandstone	Vinton, fine-grained sandstones and shales Allensville, coarse sandstone Byer, fine-grained sandstone Berne, evenly bedded conglomerate
Cuyahoga formation	Shale with thin sandstone beds, chiefly in lower portion; shale much in excess of sandstone Thickness, 300 feet	Black Hand, massive, coarse, cross-bedded conglomerate Fairfield, coarse sandstones and conglomerate Lithopolis, shales with fine-grained sandstones, the latter in excess of shales Total thickness, 600 feet
Sunbury shale	Sunbury shale	Sunbury shale
Berea grit	Berea grit	Berea grit
Bedford shale	Bedford shale	Bedford shale

The following table shows briefly the formations present in different places in the four western townships of Vinton County, and in some detail, the chief changes in character. There is little change from place to place in the members or formations of the Logan, but the beds of the Cuyahoga change rapidly. This table shows the transition zone between the two columns of the last table.

Table showing the formations in the western townships of Vinton County

Coal Measures	Western margin of Vinton County	Eastern part of Eagle Township. Western part of Richland Township	Central part of Jackson Township. Eastern part of Richland Township	Northeast part of Jackson Township
	Not present	Coal Measures present on higher hilltops	Coal Measures present on all hilltops and upper slopes	
Logan	Vinton member. fine-grained, bluish-gray sandstone and sandy shales, thin-bedded, often lamellar, no essential difference in character from place to place, but much difference in thickness. This is greatest, 80 to 90 feet, in eastern Eagle Township, but is absent in the northwest part of Richland Township. This is due to erosion of the beds before the Coal Measures were formed.	Allensville member. Coarse sandstone in beds from a fraction of an inch to two or three feet thick, remarkable for the uniform size of its grains, up to one or three millimeters in diameter (one-eighth inch). These are interbedded with fine-grained sandstones indistinguishable from those of the underlying Byer, into which it grades. It is 12 to 16 feet thick, and uniformly distributed over all four townships.		
	Byer member. Fine-grained, gray sandstone, always buff on outcrop, in thicker layers than those of the Vinton. It varies from 50 feet in thickness in the northeast part of Jackson Township, to 100 feet on the west line of the county.			
	Byer, 100 feet thick	Byer, 60 to 75 feet thick	Byer, 60 to 75 feet thick	Byer, 50 feet thick
Cuyahoga	Berne member. Coarse conglomerate sandstone, two inches to two feet thick, thickest and coarsest at the northeast, thinner and with much smaller pebbles at the southwest, but everywhere present, except that it has not been observed in the southwest part of Harrison Township, though it may be present.			
	Cuyahoga shale	Black Hand sandstone member	Black Hand sandstone member	Black Hand conglomerate
	Soft, gritty, gray clay shales with numerous sandstone layers a foot or less in thickness	Sandstones finer grained than to eastward, no pebbles, bedding even, tendency toward lamellar splitting; some beds shaly. Fossils present. Thickness 100-120 feet	Coarse sandstone, pebbles few or absent. Fossils present. Below drainage in eastern part of Richland Township	Coarse conglomeratic sandstone with quartz pebbles up to one-fourth or one-half inch in diameter abundant. Bedding fairly regular. No fossils. Bottom below drainage
	Cuyahoga shales, gray clay shale, sandstones thin, shales much in excess of sandstone. Base not exposed	Cuyahoga shales, gray, gritty clay shale with sandstone layers, shales in excess of sandstone		Underlying sandstones and conglomerates much greater in amount than shale to a total thickness of perhaps 400 ft.

CUYAHOGA FORMATION

The term Cuyahoga¹ has some variation in meaning in the following description. It designates the entire series of rocks from the Sunbury shale to the base of the Logan, whether they be the sandstones of the Hocking Valley or the equivalent shales of the Scioto Valley. The shales we do not hesitate to call Cuyahoga, because the type Cuyahoga formation is a shale, but the sandstones, where present, have been given other names, and, by a kind of traditional practice inherited from the past, the name Cuyahoga is not often applied to them. Hence, the name may designate the whole thickness where it is a shale, as along the western line of the county, or it may designate only the shaly portions in places where much of this thickness is sandstone and separately named, as a few miles to the east.

Black Hand member.—To the north and northeast from the Vinton County Waverly, that is in Benton, Laurel, and Falls townships of Hocking County, the Black Hand is a massive, conglomeratic sandstone, forming numerous prominent ledges on all streams which cut deeply into it. Some of the finest cliffs are to be seen in the southeast quarter of Benton Township on Feed Race or its tributaries, and although it does not form such prominent ledges, the conglomerate is well developed on Goose Creek in the southwest quarter. These occurrences are very near the north line of Vinton County. The heads of the larger streams, where flowing over the Logan, are of slight fall, in valleys with mature, evenly sloping sides and narrow bottom lands bordering the streams. This is ended abruptly at the point where the stream cuts into the top of the Black Hand, by a precipitous fall, sometimes 100 feet or more in height, and from that point onward, the valley is very rugged and bordered by abruptly sloping sides or perpendicular ledges.

Immediately south of this in Jackson Township of Vinton County, changed conditions are present. The topography is different. Ledges comparable to those of Hocking County are entirely wanting and the outcrops of the Black Hand are, at the most, only a few feet in height, and occur only in banks and beds of streams exposed to washing and in roadside cuttings. The streams flow without any appreciable change in gradient from the Logan rocks into the Black Hand. There is even no change in the hillside slopes at the top of the Black Hand. The

¹The name Cuyahoga, as used in this bulletin, covers a somewhat greater thickness of rocks than in the earlier reports of central Ohio, by including the Black Hand member. So used, it designates a very distinct group of sedimentary rocks, which have had much in common in their history, a group for which a single name is needed. It is not at all certain, however, that Cuyahoga is the proper name. As it was originally used, the name covered two or three hundred feet of shales and sandstones overlying the Berea sandstone in the Cuyahoga Valley of northern Ohio, which are readily subdivisible into several members that are not certainly intimately related, and at most, the name appears to cover there only the lower part of the beds here called Cuyahoga.

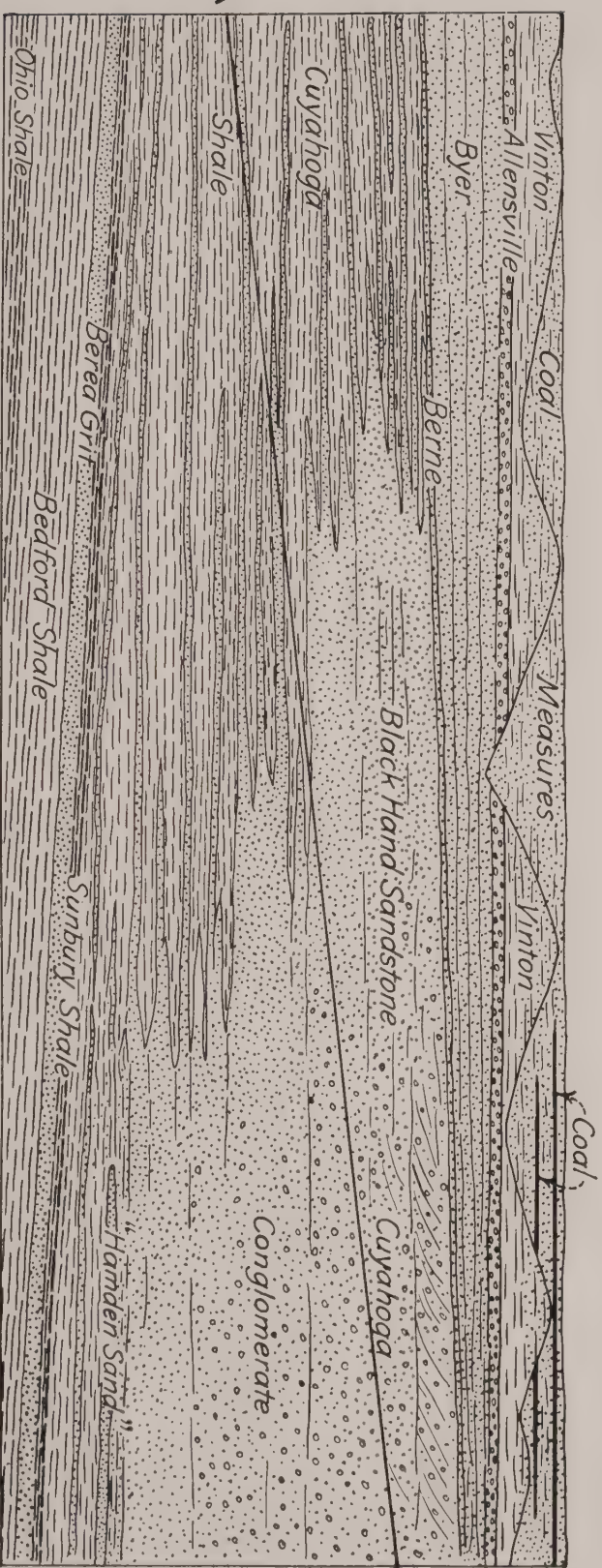
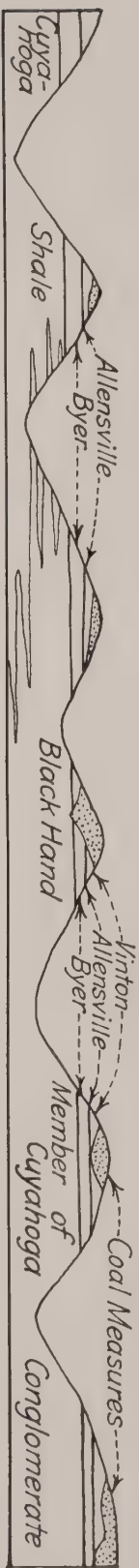


Fig. 1. Diagram of the Waverly rocks from east to west across western Vinton County, to show the general relation before streams had cut them into hills and valleys. The oblique line, A-B, near the middle shows the approximate position of the valley bottoms, and the diagram at the top, which shows how the stream valleys have cut into the rock layers, was taken along this line.

larger streams are bordered throughout much of their length by narrow bottom lands, seldom more than a few hundred feet in width, to which the hills usually slope more or less abruptly, and often steeply, but nowhere as cliffs.

In the northern and eastern part of Jackson Township, as far south as the Richland Township line, the Black Hand is a conglomerate with numerous quartz pebbles up to one-fourth or one-half inch in diameter, both scattered through the body of the sandstone and in thin streaks, but without the capacity to form ledges. Toward the southwest part of Jackson Township the pebbles decrease rapidly in number and within two miles of a locality where they are abundant, they may disappear entirely. The Black Hand becomes a finer grained sandstone without pebbles, bluish-gray in color, weathering dull gray or buff; the bedding is in regular layers, thick, but tending to split on exposure into pieces two to four inches thick. There is considerable evidence of gentle current action in the fine lamination which occurs throughout. It weathers by splitting off large slabs parallel to the outcrop face, irrespective of the bedding. Outcrops are often discolored by a white efflorescence. The stone is apparently wholly valueless.

The coarse sandstones and conglomerates of Hocking County are without fossils. As these sandstones become less coarse, fossils make their appearance, often while there is yet a considerable pebble content. These are the first localities south of Lancaster in Fairfield County where the Black Hand has carried a marine fauna. This fauna is fairly abundant in the upper part of the Black Hand but the lower part carries only *Gamarotoechia*.

The Black Hand of Richland Township is much like that of Jackson Township except that pebbles are seldom seen. It is found extensively only in the western and northern portions, where only the upper part is exposed. It is below drainage in the southeast portion.

This sandstone is found as far west in Eagle Township as the Narrows of Salt Creek where it is 121 feet thick. (See section near end of chapter for detail.) This is about three-fourths of a mile south of the Hocking County line.

Two miles southwest of this section, a few poor outcrops are seen in the gully of the road from Eagle Mills over the hill to Jimtown, on the eastern side of the hill. These serve to demonstrate the almost complete passage of the Black Hand sandstone into shales. The Berne pebble bed which is found everywhere immediately on top of the Black Hand is present but was not seen in position. The horizon was identified by a number of large, loose blocks; it appears to be about 10 inches thick and consists largely of pebbles one-eighth to three-sixteenths of an inch thick. Nothing can be seen for 20 feet below it, but still lower

there are about 20 feet of gray clay shales and sandstones very like those of the Cuyahoga, but occurring at a horizon which, two miles to the eastward, is in the upper part of the Black Hand. Above the Berne pebble bed the Logan sandstones are very poorly shown, but at 90 feet higher the loose debris from the Allensville pebble bed appears, serving as an excellent check on the identity of the Black Hand. Below the section scattered shale outcrops of the Cuyahoga, possibly the horizon of the Black Hand, occur for half a mile or more along the road down the stream. The section is a very poor one, but there can be no doubt of the horizons and it serves to show in connection with the one at The Narrows, the passage into shale of probably the whole of the Black Hand sandstone within two miles.

No section was seen west of this point until well within Harrison Township of Ross County, three to five miles distant, where sections show that the Black Hand has passed entirely into a shale, the horizons of the Allensville and Berne pebble beds being readily identified, and serving as checks.

In Harrison Township lying south of the last, the Black Hand member is well shown throughout the eastern tier of sections and is essentially like that seen immediately to the eastward and to the northward. In the southwest quarter of Section 13, near the middle of the eastern line of the township, its thickness is at least 95 to 100 feet. Three-quarters of a mile northeast of Ray in the road above the Corinth church, at least 60 feet of the Black Hand is present carrying fossils. Both of these localities are within a mile of the eastern line of the township. With the exception of a few outcrops along the northern line of the township, nothing is known, as yet, of this formation over the remainder of the township, because of hasty examination of poor outcrops.

In the west central part of Section 4, where the old abandoned Jackson-Tarleton road descends from the hilltop into a short tributary of Salt Creek, poor outcrops suggest that the Black Hand is largely replaced by Cuyahoga shale. This is within 3 miles west of a locality showing 95 feet of Black Hand sandstone.

Cuyahoga shales.—These are best exposed in Eagle Township. In the eastern part on Pretty Run, only the topmost beds of the shaly part of the series are exposed below 120 feet or more of Black Hand sandstone and it is not certain that the shale is uncovered as far east as the township line. Two miles west of the east line of the township and less than one mile south of the north line of the county, in the narrow post-glacial cutting of Salt Creek, in two good sections, about 75 feet of Cuyahoga shale is exposed, overlain by 121 feet of Black Hand. In the western half of Eagle Township at many points along Salt Creek and

Pike Run and their tributaries, low banks of the shale can be seen, while along the western line of the township and just over the line in Ross County at points almost in the very heads of the tributaries, there is 200 feet of shale between the streams and the Berne member, which there directly overlies the shale. This increased thickness of exposed shales is not due to the westward rise of the strata, but is almost wholly because the upper part of the shale is the direct equivalent of the Black Hand only four miles to the eastward.

The Cuyahoga formation of the western margin of the county consists of gray, argillaceous shales, slightly gritty and micaceous, usually with more or less carbonaceous matter distributed through it in the form of small fragments whose structure is indistinguishable to the unaided eye. Alternating with the shales are moderately coarse, reddish-brown sandstone layers which are usually three to six inches thick, the total thickness of the shale being much in excess of that of the sandstone. Their reddish-brown color is probably due to surface weathering, for the color of the unweathered rock deeper in the hills appears to be bluish-gray. In the western part of the township occasional sandstone strata are encountered with a thickness of two or three feet, at horizons where the ratio of sandstone to shale increases through a vertical thickness of several feet. These are the westward extensions of the thick beds of coarse sandstone and conglomerate which are present in the conglomerate area a short distance to the eastward.

The shales of the Cuyahoga are frequently exposed in the southwestern part of Harrison Township, in the B. & O. S. W. railroad cuts just across the line in Ross County. There are there many thin, reddish-brown sandstones up to a foot in thickness, scattered through greater thickness of shale.

In the extreme northwest corner of Richland Township, the Middle Fork of Salt Creek has cut a few feet into the shales below the Black Hand member.

The total thickness of the Cuyahoga shales in the Scioto Valley is about 300 feet, about half the thickness of the equivalent conglomerate to the eastward. As a result, the top of the Cuyahoga formation, when traced from the conglomerate area of Hocking County westward into the shale region, declines somewhat in altitude, contrary to the general easterly dip of the rocks. This can be easily detected across the western part of Vinton County.

The fauna of the Cuyahoga shales is almost negligible, so far as it is known at present. Two specimens of *Grammysia hannibalensis* Shumard have been obtained from the sandstone beds, one on Salt Creek at the "Narrows" section, the other on Pike Run near the north line of the county. Both were of the type figured from northern Ohio by Meek in Vol. II of the Paleontology of Ohio, plate 16, figs. 5a-c.

*History of the formation of the Cuyahoga and the significance
of change from conglomerate to shale*

The cause of the remarkable passage from conglomerate to shale within six or eight miles lies in the origin of the rocks themselves. They were originally formed as muds, sands, and gravels, layer on layer, which eventually hardened into shale, sandstone, and conglomerate.

It is clear from the study of these rocks over several counties¹ that at the time these rocks were forming, Ohio was not a region of hills, valleys, and streams, but of shallow seas in which sediments were being deposited. The eastern portion of Vinton, Hocking, and Fairfield counties was an area of accumulation, to a thickness of 600 feet, of coarse conglomerates and sandstones, under strong currents sweeping gravel from the southeast. The coarseness of the material, the abundance of cross bedding and its direction of slope to the northward all attest this. The conglomerates may be the result of delta growth under stream action, or bar development under strong oceanic currents; which is not clear.

The whole was later buried under the Coal Measures rocks, and in time became a land area subject to stream erosion. The Coal Measures have since been removed from Fairfield and in part from Hocking County, where the structures in these conglomerates can be easily observed in the stream valleys and cliffs which have since been cut into rocks. In the central and eastern portions of Vinton County, however, the Coal Measures still cover the conglomerates from sight.

While these conglomerates were forming under the influence of northwardly sweeping currents, quiet water lay to the westward in which muds were settling, which have since been changed into the Cuyahoga shales. The thickness of this shale is about half that of the conglomerates, 300 feet. The shales of western Vinton County are of this sort. Between the area of strong currents and gravel accumulations and the area of quiet water and mud accumulation, lay a zone in which the currents were of rapidly decreasing strength, in which the deposits grade from gravels into coarse sands, fine sands, then into muds with thin sandstones. This is the transition zone now exposed in Jackson, Eagle, Richland, and Harrison townships.

No fossils are found in the conglomerate area. Clearly the currents were too strong and tempestuous, and the sands and gravels too shifting, to permit the shell life of the sea floor to live there. But in the evenly bedded sandstones of western Vinton County, which show by their structure that such currents and shifting sands were not present, marine fossils are often found in abundance. The quieter sea floor of this area must have been favorable to shell fish of many sorts.

¹Hyde, J. E., *Stratigraphy of the Waverly Formations of Central and Southern Ohio*. Jour. Geol., Vol. XXIII, pp. 655-682, 757-779. 1915.

LOGAN FORMATION

The Logan formation consists of fine-grained sandstones, shaly sandstones, and sandy shales, with only minor amounts of coarse material. It is readily divisible into four members, three of which can be traced, with changes but without loss of essential character, from the Ohio River in Scioto County to Wayne County, 160 miles, and the Berne member from Vinton County to Wayne County, 120 miles. The sandstones are never as coarse as the Hocking County conglomerates of the Cuyahoga, and the shales rarely as soft and clayey as those of the Cuyahoga. The different members all carry fossils. The whole aggregate bespeaks much more uniform sea-floor conditions over wide areas, and much quieter wave and current action, such as can be readily understood on the assumption of deeper waters, farther from shore, than those which obtained in Cuyahoga time.

The Berne conglomerate.—This bed, although thin, is persistent throughout the entire western part of the county, with the possible exception of the southwest part of Harrison Township of which nothing is known. Apparently it is never more than two feet in thickness, but it is always present and very regular.

In Jackson Township it is uniformly about two feet thick and composed very largely of pebbles one-fourth to one-half inch in diameter. It decreases in thickness and the size of the pebbles diminishes both southward and westward.

Near the northern line of Richland Township, in the section one-half mile north of Allensville (to be given later) it is 18 inches thick and composed largely of quartz pebbles one-fourth to one-half inch in diameter. One-half mile south of Allensville in the road and stream bed coming down to this town from the south, the conglomerate layer is 20 inches thick. Here many of the pebbles are three-eighths to one-half inch in diameter, but they are mostly smaller. One and one-half miles farther south, on the line between sections 17 and 20, it is only four to six inches thick. Two miles farther south, southwest, in the northeastern quarter of Section 31, it is from two to ten inches thick, the pebbles all less than one-fourth and mostly about one-eighth of an inch in diameter.

There is little to be said of it in Harrison Township. It has been seen at several points in the sections along the eastern line of the township, but it has not been observed west of this because of poor outcrops and less thorough search. As far as seen, it is persistently ten inches to one foot in thickness and composed, as usual, of evenly graded quartz pebbles from one-eighth to three-sixteenths of an inch in diameter and less.

The Berne bed is present throughout Eagle Township with a thickness of from eight inches to one foot, and consisting of pebbles

mostly from one-eighth to three-sixteenths of an inch in diameter or less. It rests on the Black Hand member in the eastern part. Whether or not it rests directly on shales at any point in the western half has not been determined, but two and one-fourth miles west of the western line, in Ross County, it holds such a relationship.

The Berne member over Hocking and Fairfield counties forms the top of the great ledges of Black Hand conglomerate, and there is little resemblance to the overlying fine-grained sandstone of the Logan. In Jackson Township of Vinton County, similarly, its natural association seems to be with the underlying conglomeratic sandstone. By some observers the Berne might be aligned with the Cuyahoga rather than with the Logan, and the present writer thought of it in this way for years.

To understand it, the Berne must be considered over its whole extent. There is much in its character, structure, and relation to the underlying conglomerates, sandstones, and shales, for it rests on all at one place or another by a sharply defined contact, to show that this bed was formed after the strong current action of Cuyahoga time had ceased, when uniform conditions prevailed over the whole area. It is the result of smoothing off by gentle currents on the sea floor of the top of the high-standing Cuyahoga conglomerate areas, and the spreading of this coarse material over wider areas than the Cuyahoga conglomerates occupy. This current action was not too strong to prevent certain marine shells from living at all places on the floor at this time, for fossils are found in the Berne conglomerate at many places, even over the center of the maximum development of the Hocking Valley Black Hand conglomerate.

Considered as a conglomerate only, it would seem to belong with the underlying conglomerates, but its history belongs with the history of the Logan, and for that reason, it is here regarded as the result of the opening episode of Logan time. The underlying conglomerates were the source of the material in this opening episode. This was probably a submergence of the sea floor and deepening of the waters, with complete cessation of the strong local current action of Cuyahoga time, and the introduction over the sea floor of gentle bottom currents and widespread wave action which slowly dispersed the upper part of the high-standing masses of Cuyahoga or Black Hand conglomerate.

Byer sandstone.—This is a fine-grained, evenly bedded, yellow sandstone with occasional shaly layers. It is, however, very resistant and has stood in the walls of railroad cuts on the B. & O. S. W. for years. The beds are usually from three to six inches or one foot in thickness. It is readily distinguished from the underlying Black Hand which is coarser, more grayish in color, and weathers by breaking into blocks across the bedding.

The thickness varies from 50 feet to about 90 feet. It is least in northeastern Jackson Township, increases somewhat to the south and more to the west. In the southwest corner of Jackson it is between 60 and 65 feet thick. Just north of Allensville in Richland Township, it is 55 feet, two miles to the south, 60 feet (barometer). Three and one-half miles south, southwest from the last, the interval obtained is 68 feet, again by barometer, but it is by no means certain that the base of the upper coarse zone which lies above this sandstone was seen at the last outcrop. This is on the Thomas Doles estate one mile north of the Jackson county line. At the "Narrows" section on Salt Creek in Eagle Township, it is at least 75 feet thick. Two miles farther southwest on the road over the hills from Eagle Mills to Jimtown, it is about 90 feet thick. In Harrison Township of Ross County, two and one-fourth miles west of the Eagle township line, it is 116 feet thick.

The Byer sandstone thickens westward, in rough proportion as the underlying Cuyahoga formation decreases in thickness, the result of quiet current action on the ocean floor, which gradually filled up the irregular depressions left by the tempestuous local currents of Cuyahoga time.

It is often difficult or impossible to locate the exact top of the Byer member, because it passes very gradually into the Allensville, the lowest, earliest coarse streaks of which are very thin and easily escape detection. It is, furthermore, almost certain that the first few thin streaks which are present in one section may be absent a short distance away. Nevertheless, it is certain that the bed more than doubles in thickness in 16 miles, as the thickness of the Cuyahoga decreases to the westward, away from the Hocking Valley conglomerate area.

Fossils are not uncommon, and in places are very abundant. *Chonetes* sp. and *Rhipidomella* sp., always the same species, are the only ones noted.

The name of this member is derived from the very good outcrops in the B. & O. S. W. railroad cuts above Byer in Jackson County.

The Allensville bed.—This bed is distinguished by the occurrence of excellently assorted, very coarse sands or very fine quartz pebbles. The largest grains are about one-eighth inch or three millimeters in diameter and range down to about one-half or one millimeter. The size diminishes somewhat to the west, where they are commonly one-thirty-second to one-sixteenth of an inch in diameter. The assortment is remarkable. This material is distributed in thin beds from a fraction of an inch to a few feet in thickness, which alternate with fine-grained, yellow sandstones which in themselves are indistinguishable from those of the Byer. The coarse streaks are usually thin in the lower part, becoming thicker in passing upward, the fine-grained beds becoming thinner and disappearing at the same time. The top-

most bed of coarse material is usually several feet thick and is the best developed and most persistent. The top of the member is always very sharp with no transition to the overlying Vinton beds. Occasionally the thinnest beds of coarse material consist of a parting between two fine-grained beds on which one layer of the coarse grains, one grain thick, has been laid down. These grains are packed until they touch, as in a mosaic, but one grain does not lie on another. The thickness of the member is seldom determined exactly, for the reason indicated in the discussion of the Byer sandstone, that the exact base is so uncertain. The bed is always high in iron content, and the coarse streaks are cemented with limonite which is probably a secondary product of recent weatherings.

In the northwest quarter of Section 4, Jackson Township, on the head of Goose Creek near the north line of the county, the section of this horizon is as follows from the top downward:

	Ft.	In.
Very coarse sandstone, overlain by shales of the Vinton member.....	1	3
Massive, fine-grained sandstone.....	4	0
Very coarse sandstone, not as pebbly as the lower one.....	1	0
Fine-grained sandstone.....	2 or 3	0
Very coarse sandstone, or better, a fine conglomerate composed of pebbles $\frac{1}{2}$ to 3 mm. in diameter, very evenly assorted.....	2	6

Near the middle of the south line of the township at the forks of the road in the southeast quarter of Section 34, this horizon occurs in the stream bank, the base being possibly below the stream bed. This outcrop and the one near Allensville, next described, should be considered the type outcrops of the member, since the name is given from this locality. The exposed portion is here 12 feet thick and consists of alternating layers of fine conglomerate, coarse sandstone, and fine-grained sandstone. The coarse streaks are more abundant in the lowermost three feet where they are mostly two or three inches thick, alternating with fine-grained layers. The topmost two feet consists almost entirely of this pebble conglomerate, the pebbles being up to one-eighth inch or three millimeters in diameter. The interval between the lower and upper pebble layers consists largely of fine-grained sandstones with a few thin coarser sandstones and pebble streaks of a few inches each. In the extreme southwest corner of the township in Section 31, on the line between Richland and Eagle townships, it is 16 feet in thickness, the uppermost three feet of which forms a well marked pebble horizon, the pebbles seldom exceeding one-sixteenth of an inch in diameter. The remainder of the bed is composed very largely of fine-grained sandstones with numerous thin streaks of small pebbles on the bedding planes.

The member is present at all points in the western half of Richland Township, wherever search has been made for it, unless, as is occasionally the case, it has been removed by the erosion plane between the Waverly and Coal Measures series. The only place in this township where its thickness has been determined is in the section north of Allensville near the north line, where it is not certain that the base was seen, but it is at least 13 feet thick. The uppermost three feet, eight inches, consists of small, rounded pebbles one to two millimeters in diameter with a few thin streaks of fine-grained material; the lower portion is but poorly shown and consists largely of fine-grained, Byer-like sandstones with numerous thin streaks of small pebbles on the bedding planes. The more striking pebble bed at the top of this zone has been seen at several points in the southwest part of the township but the outcrops are not good.

It is well shown at at least one point in Harrison Township, west central part of Section 4, where the old Jackson-Tarleton road descends to Salt Creek. It is there over 15 feet thick. Usually, however, it is only poorly shown and occasionally, as at Ray, was removed during the post-Waverlian period of erosion.

The Allensville bed is poorly shown, when shown at all, in Eagle Township, but it is persistent throughout. In the "Narrows" section only the topmost eight inches is shown in position. In the northwest corner of Section 25 south of Pretty Run, it is at least eight feet thick, the topmost foot consisting of coarse sand grains or very fine pebbles, the remainder of thin streaks of such material interfingered between greater thicknesses of fine-grained sandstones like those of the Byer.

The Vinton member.—The Vinton is an uninteresting series of sandstones and shales. The sandstones are fine grained, thinner bedded, and more platy and harder than those of the Byer. In color they are more apt to be gray than those of the Byer, although yellow, due to weathering, is common. Under cover, where weathering has had no effect, they are undoubtedly bluish gray. The shales are gray and sandy. They are more abundant in the lower 40 or 50 feet, just above the Allensville bed, whereas the sandstones are more abundant higher up in the member. Fossils are seen only rarely.

The thickness of the member depends wholly on the attitude of the post-Waverlian erosion plane, as is shown below.

*The post-Waverlian erosion plane and the thickness of the
Vinton member*

After the Waverly formations had accumulated to an unknown thickness, the region was uplifted and became a land area. Streams carved out valleys with hills between them. When the Coal Measures were laid down on the irregular surface thus formed, the valleys were

filled first and finally the hills were covered up and preserved. These irregularities can be readily detected, although it is seldom possible to trace an old valley or hill any distance, and never possible to see one as we see them today.

In the northern and central part of Jackson Township, as far as observed, the Vinton member is 70 to 90 feet thick. Over the southern tier of sections, this interval has been reduced to about 18 to 40 feet. At the locality in the southeast quarter of Section 34, where the Allensville bed is well exposed, the overlying sandy shales are reduced to about 18 feet. In the hill northeast of Allensville (see section) on the south line of the township, it is about 40 feet.

In Richland Township, one mile south of Allensville, very near the point where sections 8, 9, 16, and 17 touch, the base of the Coal Measures is only 60 feet above the base of the Logan (determined by barometer) and the Allensville bed, at least the topmost conspicuous portion, was removed before the Coal Measures were formed. One mile south of the last locality, the base of the Coal Measures is again at an elevation of 30 or 35 feet above the coarse zone, with the usual sandy shales intervening. Three miles south, southwest of Allensville in the southwest quarter of Section 20, where the Allensville-Byer road passes up a small valley to the divide between Middle Fork of Salt Creek and Pigeon's Roost Creek, a few small outcrops show, not very well it is true, how the erosion plane is here above the stream bed and there below it. In Section 31 two miles southwest of the last, on the land of Thomas Doles, it again lies only a few feet above the Allensville. Best of all, however, are the massive Coal Measures sandstones which have been abruptly let down into the Logan at Richland on the B. & O. S. W. railroad, within the Richland township line.

In Harrison Township, three-fourths of a mile northeast of Ray in the southeast corner of the township, in the section to be described later, this erosion plane has cut away the Allensville pebble bed and a portion of the underlying sandstones, leaving a total thickness of the Logan of only 55 feet. One mile northwest of this point, where the road goes over the hill in the northwest corner of Section 35, the base of the Coal Measures lies at least 65 feet above the top of this pebble bed (barometric determination). Adopting the thickness just given for the combined Byer and Allensville beds, this places the thickness of the Logan formation at 135 feet, an increase of 80 feet in about one mile, due entirely to the irregularity of the erosion plane.

The relation of a 30-inch coal bed to this unconformity was carefully worked out with the aid of core tests of the coal, in the eastern part of Section 25, in the southeast portion of Harrison Township. The abrupt disappearance of the bed greatly puzzled the owners. Occurrences of the bed were known some 500 yards apart, but between them it could not be found, even in core holes. Inspection of the

scattered test cores and the poor outcrops between these localities showed Logan sandstones extending to an altitude 50 or 55 feet above level of the 30-inch bed, an old Logan hill which had projected, island-like, above the swamp which eventually became the 30-inch bed. A second bed a few inches thick reported to overlie two feet of fire clay, which lies normally 55 feet above the 30-inch coal, passed over the old Logan hill without interruption. This relation shows that the hill had been completely buried under Coal Measures sediments before the second coal swamp was formed. Possibly if search had been made for the upper bed a little to one side, it would have been found absent and that the hill had risen too high to be entirely covered by this second swamp. It appears certain that some of this old land surface, on which the earliest Coal Measures rocks were formed, was too high to admit of the formation of the upper bed.

In the extreme southeast corner of Eagle Township on the line between Eagle and Jackson townships, a roughly measured section shows 75 feet of the Vinton below the Coal Measures. The pre-Pennsylvanian erosion plane in this township was not cut down to the extent that is noticed farther east and southeast.

SECTIONS OF THE WAVERLY ROCKS

Following are typical sections of the Waverly of western Vinton County, with an additional one from within Ross County. These exhibit all phases of the Waverly of this region.

Section in Northwest Jackson Township

In the northwest corner of Jackson Township in the western half of Section 5, on a small stream entering Pretty Run from the north, the following strata were measured, the thicker members by barometer:

Coal Measures (Pennsylvanian system)

Mississippian system

Logan formation, total thickness 124 feet.

<i>Vinton member, thickness about 70 feet.</i>		Ft.	In.
3	Fine-grained, rather hard and tough sandstones, gray or light buff in color; layers two to four inches thick; shaly in places.....	35	0
2	Sandy shales and shaly sandstones, bluish-gray to buff in color.....	35	0
1	Covered.....	10	0

Mississippian system

		Ft.	In.
<i>Allensville member</i> , at least 4 feet, top not shown.			
2	Hard, fine-grained sandstone, belonging in the middle of the Allensville.....	1	6
1	Coarse sandstone, consisting of very coarse sand or small pebbles.....	2	6

Byer member

Fine-grained, yellow sandstones, some beds as much as one foot thick, but much of it tending to split more thinly.....		50	0
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Cuyahoga formation, 32 feet seen.*Berne member*

Hard, massive bed of conglomerate, composed largely of pebbles one-fourth to one-half inch in diameter.....		2	0
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Black Hand member

Coarse sandstones with numerous scattered quartz pebbles and occasional pebble streaks, none of which are more than two or three inches thick. The pebbles show a marked decrease in number and size from what is present only a mile or two to the northward. These sandstones split readily on exposure into layers three or four inches or more in thickness, whereas the ones in the upper part of the formation to the north, split with difficulty or not at all.....		30	0
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Section in Eagle Township

The best section which has been seen in Eagle Township, in fact the best that has been seen in several townships, is on Salt Creek, three-fourths of a mile south of the Hocking county line in Section 11. Salt Creek is one of the numerous streams flowing out from the glaciated area which previous to the period of glaciation flowed northward. Thrown across the divide above its former headwaters by the damming action of the ice, it has cut across this divide and has held to the new course thus formed since the melting of the ice sheet. The section here described is exposed in the east wall of the valley of Salt Creek in the narrow portion near where formerly stood this old divide. The stream has cut against the bank at this point to such an extent that perhaps 150 feet or more of the section is exposed, but it is so steep that most of it is inaccessible. Just south of the bank and distant perhaps 50 yards, a road winds up over the hill and the cuttings for it have exposed the strata above those seen in the stream bank, so that, in all, an almost continuous section of over 350 feet can be measured.

The measurements are all by hand level, except the thickness of the Cuyahoga which was determined by barometer and the thickness of the Black Hand which was obtained by deducting this barometric figure from the elevation of the top of the Black Hand above Salt Creek, 197 feet, determined by the hand level.

This section is of great importance because of the rapid change from sandstone into shale observed in the Black Hand farther westward, and it is fortunate that it is so exceptionally well exposed.

Coal Measures (Pennsylvanian system)

Not seen in position in the immediate section but undoubtedly present, as is shown by the loose fragments of coarse, Coal Measures sandstones; better shown about one-fourth of a mile to the eastward.

Ft. In.

Mississippian system

Logan formation, total thickness, 162 feet.

Vinton member, thickness about 80 feet.

3	Covered to what appears to be about the base of the Coal Measures; included within the Logan because of the presence of loose material from the Logan formation.....	35	0
2	Fine-grained, yellow sandstones, seldom more than two or three inches thick, usually weathering into thin laminae; poorly shown.....	18	0
1	Hard, light gray or buff, sandy shales, very gritty; not well shown.....	27	0

Allensville member

The topmost eight inches only is here exposed. This is a hard bed composed of quartz pebbles all less than one-eighth of an inch thick. That the bed is several feet thick is certain from loose debris.....

8 +

Byer member, thickness less than 81 feet, 9 inches.

3	Fine, yellow sandstones, beds six to eighteen inches thick, not all shown. A few feet of the top belongs to the Allensville.....	48	3
2	Sandy shale.....	5	6
1	Fine-grained, yellow sandstones for the most part two to six inches thick.....	28	0

Cuyahoga formation, total thickness, 122 feet.

Berne pebble bed

Consisting of quartz pebbles, mostly about one-eighth of an inch in diameter but not infrequently one-fourth to one-half inch in diameter....

1 0

*Mississippian system—Continued**Cuyahoga formation, total thickness 122 feet.**Black Hand member*

Ft.

In.

Moderately coarse, gray or yellowish sandstones, much coarser than those of the Logan formation layers, usually two to six inches, rarely one foot thick, tending to split into thinner layers on weathering. Occasional shaly layers are not uncommon but they are not of sufficient importance to consider the section transitional to the shale phase of the formation which is found only two or three miles to the westward. The topmost 50 feet is exposed in the road, the remainder in the upper part of the stream bank. Base of formation not well defined, about 10 feet being transitional from the Cuyahoga shale to the Black Hand. This portion is included in the measurements of the former. The lowermost 20 feet of the Black Hand, as here defined, appears to be more shaly than the mass of the formation; this shows itself in the somewhat less massive appearance of this portion of the cliff. .

121 0

Cuyahoga shales

Gray, clay shales alternating with sandstones. The shales are gritty, micaceous, and with a certain amount of carbonaceous material disseminated in small fragments; the sandstones are moderately coarse, (coarser than those of the Black Hand) and usually a rich brownish red in color, probably due to surface oxidation, and not original. This color has not been observed in the sandstones of the Black Hand at this point. The shale beds are much thicker than the sandstone layers. In the uppermost transitional eight or ten feet, the shales and sandstones are of about equal thickness, the sandstones retaining their coarse nature and reddish color through the transition. Although the contact is not such that one can place his finger on it, a change other than mere passage from a condition yielding a more shaly sediment to those yielding a sandstone is apparent, both in the fact that the sandstones of the Black Hand weather readily into thinner laminae, while those of the Cuyahoga do not, and in the coarser grain of the Cuyahoga sandstones. A single specimen of *Grammysia hannibalensis* of the type found in northern Ohio was found in the sandstones near the top of the Cuyahoga. .

75 0

Level of Salt Creek.

One-half mile southwest of this section, on the line between sections 10 and 15, and on the west bank of Salt Creek, about 70 feet of Cuyahoga shale is shown in the steep bank above the road, the uppermost five or ten feet of which is transitional to the Black Hand. Above this 45 feet of the Black Hand is shown. The rocks of both formations are indistinguishable in character from those of the same horizons in the section just given, and the transition from one formation to the next is, apparently, exactly similar.

Section north of Allensville, Richland Township

This was measured along the road as it passes up the hill one-half mile north of Allensville in the eastern half of Section 5.

<i>Coal Measures (Pennsylvanian system)</i>	Ft.	In.
Lower part not seen but recognized by the coarse sand which is abundant in the road.		
<i>Mississippian system</i>		
<i>Logan formation</i> , total thickness about 108 or 110 feet.		
<i>Vinton member</i>		
Yellowish, sandy shales with occasional thin sandstones, upper 10 feet not seen and uncertain...	40	0
<i>Allensville member</i>		
Base not certainly seen. The topmost 3 feet 8 inches consists of small pebbles with thin streaks of fine-grained sandstone; pebbles ranging in thickness from one to two millimeters. The lower portion consists largely of fine-grained sandstone with a few thin beds of small pebbles or very coarse sand like that in the upper part.	13	0
<i>Byer member</i>		
Fine-grained, yellow sandstones, fairly thick bedded but not well shown in the upper half...	55	0
<i>Cuyahoga formation</i> , exposed, 40 ft. 6 in.		
<i>Berne member</i>		
Composed almost wholly of quartz pebbles one-fourth to one-half inch in diameter, many larger	1	6
<i>Black Hand member</i> , thickness seen, 39 feet.		
2 Moderately coarse sandstone, no pebbles noted, yellowish or brownish in color, but otherwise like those immediately below. Color doubtless due to weathering.....	24	0
1 Moderately coarse sandstone, blue gray in color, showing method of weathering typical of the Black Hand.....	15	0

Base of section seen to within a few feet of the level of Middle Fork of Salt Creek.

Section near Ray, Harrison Township

The following section was measured three-quarters of a mile north-east of Ray and a half mile above the Corinth church, at the sharp angle of the road near the east line of Section 35:

Coal Measures (Pennsylvanian system)		Ft	In
Consisting of coarse sandstone and sandy shales. The lowermost two feet is a coarse sandstone with an abundance of cherty limestone pebbles containing Bryozoa		34	0
<i>Mississippian system</i>			
Logan formation, total thickness, 55 ft. 2 in.			
Byer member			
6	Fine-grained, light gray or yellow sandstones, mostly 3 to 6 inches thick, some sandy shales..	10	6
5	Covered	15	9
4	Thin sandstones with sandy shales; <i>Chonetes</i> sp. and <i>Rhipidomella</i> sp. are present	4	0
3	Mostly thin-bedded, fine-grained, yellow sand- stones two or six inches thick with some shaly layers	16	0
2	Gray clay shale, soft, with little grit	5	6
1	Fine-grained, yellow sandstones, beds one foot thick near base but lamellar near the top	3	5
Cuyahoga formation, thickness seen, 126 feet.			
Berne pebble bed			
	A pebble bed composed of quartz pebbles well assorted and rarely more than one-eighth of an inch in diameter	1	0
Black Hand member, total thickness at least 60 feet.			
2	Moderately coarse, dull yellowish to brown sandstone, readily distinguished from those of the Logan, but apparently finer than those at the same horizon to the eastward. Near the upper part fossils are not rare. Base not seen.	40	0
1	Covered to top of cut on B. & O. Railroad three- fourths mile southwest of the upper part of the section, by barometer, 65 ft. Within this in- terval and 45 feet directly above the top of the cut, a 15 foot ledge of Black Hand is exposed in a small abandoned quarry opening	65	0
<i>Cuyahoga shale</i>			
	Alternating gray, sandy shales and moderately coarse, yellowish or grayish sandstones; in the lowermost 10 feet the former are from four to eighteen inches thick, the latter from two to four inches; in the upper half of the cut the shales and sandstones are about equal, estimated	20	0

Section in Harrison Township, Ross County

A very good section was secured on the east side of the high ridge between Poe Run and Walnut Creek in the southeast quarter of Section 22, Harrison Township, Ross County, two miles west of the Vinton County line. Most of the section is exposed on the side of a road which passes up over a steep hill out of the head of a tributary of Poe Run, the lower part in a drain just south of this road. The Logan formation here has a total thickness of more than 175 feet, of which 116 feet, 6 inches, is Byer sandstone. Commencing at the top, the section is as follows:

Mississippian system

Ft. In.

Logan formation, total thickness seen, 175 ft. 6 in.*Vinton member*

Very poorly shown but appears, from the loose debris, to consist of the usual thinly bedded sandstones and sandy shales. By barometer to hilltops.....

50 0

Allensville pebble bed

Consists chiefly of fine-grained, yellow sandstones, sometimes two to three inches thick, with many bedding planes covered with small quartz pebbles, all less than one-eighth of an inch in diameter. Both at the top and bottom of the horizon there is a bed of such pebbles, each one foot in thickness.....

9 0

Byer member, total thickness, 116 ft. 6 in.

- | | | | |
|---|--|----|---|
| 5 | Fine-grained, yellow sandstones, layers two to six inches thick, with some hard, sandy shale. About half of thickness exposed..... | 85 | 2 |
| 4 | Thin, yellow sandstones, fine-grained, with some shale..... | 5 | 0 |
| 3 | Mostly hard, tough, sandy, gray shale with a single 18-inch sandstone near the middle and a 6 inch one near the top; no sharp contact between this member and the one below..... | 9 | 4 |
| 2 | Fine-grained, yellow sandstones, layers 8 inches to 18 inches thick with thinner layers of hard, sandy shale not at all like that of the Cuyahoga shale..... | 16 | 9 |
| 1 | Moderately soft, gray shale..... | | 3 |

Cuyahoga formation, total thickness observed, about 27 feet.*Berne pebble bed*

Consists of well assorted quartz pebbles one-eighth to three-sixteenths of an inch in diam-

eter, usually less, embedded in clay shale, the pebbles, however, comprising the bulk of the bed. Lower contact sharply defined to within half an inch..... 8-12

Cuyahoga shale at the horizon of the *Black Hand* formation, all of which has passed into a shale, 26 ft. 3 in. seen.

4	Sandy, gray shales with thin, irregular streaks of hard, gray sandstone.....	5	1
3	Gray, argillaceous clay shale with no sandstone streaks, somewhat gritty but not as hard and sandy as the member overlying.....	13	8
2	Covered.....	6	6
1	Gray clay shale.....	1	0

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CHAPTER III

PENNSYLVANIAN SYSTEM

STRATIGRAPHIC AND ECONOMIC FEATURES

The great group of rocks now known as the Pennsylvanian was first defined in Pennsylvania by Henry D. Rogers for the United States Government in 1838. It is of enormous importance for its coals, clays, shales, limestones, iron ores, sandstones, oil, and gas. The many thick coal beds in it are the dependence of great industries and provide heat for millions of homes. Its clays and shales are manufactured into a wide variety of articles for the comfort and protection of man. The limestones of this system not only enrich the residual soils but serve many useful purposes. Its iron ores were largely instrumental in the early and permanent development of the iron industry in America. Further, the sandstone at the surface provides building stone, and those deeply buried often act as storage reservoirs for the natural hydrocarbons, oil and gas. In the Appalachian field Pennsylvanian rocks cover an area of more than 50,000 square miles in central and western Pennsylvania, eastern Ohio, western Maryland, western Virginia, West Virginia, eastern Kentucky, eastern Tennessee, and northern Alabama. It is made up of four formations which are, in ascending order, the Pottsville, Allegheny, Conemaugh, and Monongahela.

In Vinton County the Pottsville and Allegheny formations are represented in full and the Conemaugh in part. The area covered by Pennsylvanian rocks is 331 square miles. Such beds appear only in small areas in eastern Eagle and Harrison townships, extend over most of Jackson and Richland, cover all of Swan and Clinton, except small patches along valley floors, and overspread entirely Brown, Knox, Madison, Elk, Vinton, and Wilkesville. The thickness of Pennsylvanian rocks in Vinton County is approximately 593 feet. The kinds represented are sandstones, conglomerates, shales, coals, clays, limestones, flints, and iron ores, most of which occur with a variety of both physical and chemical properties.

POTTSVILLE FORMATION

The Pottsville, the basal formation of the Pennsylvanian system, is represented in full thickness in Vinton County, although some members found elsewhere in the State are wanting in this territory. It

comprises all the strata from the top of the Mississippian system, upon which it rests unconformably, to the base of the Brookville coal, the oldest member of the overlying Allegheny formation. Rocks of this age are found at the surface in every township except Knox and Wilkesville but appear in small areas only in Brown, Madison, Vinton, Eagle, and Harrison. This formation has contributed to the development of the region for many years and bids fair to aid materially in future expansion. Its iron ores were worked for the old charcoal furnaces and its coal beds have provided fuel for distant markets and for local needs. Some of the clays and shales in this group of rocks are now becoming important. The thickness of the Pottsville formation in Vinton County is about 225 feet. This varies somewhat from place to place, owing to the fact that these rocks were laid down upon the uneven Mississippian floor, and because of the thinning and disappearing of beds higher in the formation. This formation is subdivided into a number of members which will be considered in order, beginning with the oldest.

Section of the Pottsville formation in Vinton County

Formation	Member	General description	Thickness	
			Ft.	In.
Pottsville...	Brookville.....	Clay, plastic, moderately regular....	4	6
		Shale, gray, siliceous.....	2	6
	Tionesta.....	Coal, thin, often absent.....		3
	Tionesta.....	Clay, plastic, only locally present....	1	6
		Shale and sandstone	19	2
	Upper Mercer....	Ore, moderately persistent.....		4
	Upper Mercer....	Limestone or flint, fossiliferous, seldom present.....		3
		Shale, dark, carbonaceous.....		9
	Bedford.....	Coal, only locally present.....		3
		Clay, plastic, siliceous.....		10
		Shale and sandstone	8	11
	Sand Block.....	Ore, generally absent.....		3
		Shale and sandstone	3	8
	Upper Mercer....	Coal, thin, shaly.....		8
		Clay, plastic, siliceous.....	2	3
		Shale and sandstone	15	9

Section of the Pottsville formation in Vinton County—Concluded

Formation	Member	General description	Thickness	
			Ft.	In.
Pottsville... (Concluded)	Lower Mercer....	Ore, kidney, local.....		3
		Shale, gray, siliceous.....	2	10
	Lower Mercer....	Shale, calcareous, fossiliferous.....	2	7
		Limestone, hard, gray, fossiliferous..		7
		Shale, dark, carbonaceous.....		6
	Middle Mercer...	Coal, usually present but thin.....		5
		Clay, plastic, siliceous.....	3	6
		Shale and sandstone.....	6	3
	Flint Ridge.....	Coal, moderately steady.....		6
		Clay, plastic, siliceous.....	3	0
		Shale and sandstone.....	10	11
	Boggs.....	Ore, locally developed.....		3
		Shale, gray.....	1	6
	Lower Mercer....	Coal, fairly persistent.....	1	6
		Clay, plastic, siliceous.....	3	0
	Upper Connoque- nessing.....	Sandstone, often replaced by shale...	53	8
	Bear Run.....	Coal, unsteady.....		10
		Clay, plastic, impure.....	2	0
		Shale and sandstone.....	8	0
	Quakertown.....	Coal, moderately persistent.....	2	2
		Clay, plastic, siliceous.....	2	6
		Shale and sandstone.....	25	0
	Huckleberry.....	Coal, thin, local.....		2
		Clay, plastic, impure.....	2	0
		Shale, gray, siliceous.....	2	0
	Anthony.....	Coal, very local.....		4
	Sciotoville.....	Clay, flint and plastic, unsteady.....	5	0
		Shale and sandstone.....	14	6
	Sharon.....	Coal, wanting, except at a few places		6
		Clay, impure.....	1	0
	Sharon.....	Conglomerate, very local.....	5	0
	Harrison.....	Ore, irregular, local.....		6
		Total.....	224	7

HARRISON ORE

Stratigraphy, extent, and value

The Harrison member, generally an impure iron ore, was named from deposits present in Scioto County and was formerly worked for iron smelting at Harrison Furnace. It is noteworthy not for its economic value, but for its relation to both the Pennsylvanian and Mississippian rocks, as it was deposited along the irregular zone of contact between these systems, and as it contains in many places material from both. It lies in the Pottsville but it is bedded in the eroded surface of the Maxville limestone, or where this is absent on that of the Logan strata. Its composition is variable. In places it is composed of a brecciated mass of siliceous fragments cemented by iron compounds. This siliceous material appears to be what was once pieces of Maxville limestone as it contains imperfect impressions of marine animal life, and as it is usually present not far distant from Maxville areas. In general, these pieces are quite angular, which suggests their origin from shore deposits by wave action or from land areas by weathering agencies. These limestone fragments through solution lost their calcium and magnesium carbonate and by replacement gained additional silica. In other words, such masses are apparently the remains of deposits of Maxville limestone that were broken up by terrestrial and littoral forces, strewn over the eroded Mississippian plain by waves and currents, then covered by Pottsville sediments, and later cemented by iron compounds deposited from ground waters that circulated along this contact zone. At other places the Harrison member is a mixture of angular, siliceous fragments and of well-rounded quartz pebbles, the whole cemented by iron compounds. The pebbles are similar in every respect to those that compose the Sharon conglomerate which in many places lies directly above the ore or not far distant. In a few localities this ore is a rather pure ferrous carbonate or, where weathered, a hydrous ferric oxide.

The distribution of the Harrison member is quite local in Vinton County as deposits were observed only in the western part of Richland Township. Near the head of Pleasant Valley in Section 30, small masses of typical material are present but poorly exposed at an elevation of about 800 feet, along the contact between shales of the Waverly and sandstones of the Pottsville. The deposits exposed vary in thickness from 3 inches to 1 foot 4 inches, and in character from loosely cemented breccia to very impure iron ore. The Harrison member is also well represented on the headwaters of Kelley Branch in Section 20. Along the road in the southeastern part of the area, the following rocks were measured:

	Ft.	In.
Pottsville formation		
Sandstone, soft, micaceous, cross-bedded.....	8	0
Breccia, with pebbles and sand, <i>Harrison</i>		8
Logan formation		
Sandstone, bluish-gray, argillaceous.....	3	0

The elevation of the Harrison member at this place is approximately 780 feet, and the thickness of the bed is 4 to 10 inches. It is made up of angular fragments from decay of siliceous limestone, of quartz pebbles, and coarse sand similar to that in the Sharon conglomerate, and of iron oxides which are the chief bonding component. Other deposits were also observed along western tributaries of Kelley Branch in Section 20. The Harrison member in Vinton County has no qualities that fit it for use and it is of stratigraphic interest purely.

SHARON CONGLOMERATE

Stratigraphy, extent, and value

The first prominent stratum at the base of the Pottsville formation is a massive conglomerate which was called Olean, in 1875, by J. P. Lesley, from exposures near Olean, New York; and Sharon, about 1879, by I. C. White, from outcrops near Sharon in western Pennsylvania. The latter name was finally adopted by members of the Geological Survey of Ohio. This stratum is widely but irregularly distributed as it extends with many wants from Cattaraugus County, New York, across northwestern Pennsylvania, central Ohio, and eastern Kentucky, into Virginia and Tennessee. In the entire field the Sharon conglomerate is erratic in thickness as well as in outline. Deposits in vertical dimension vary from 1 to 200 feet or more in Ohio and are not greatly different in Pennsylvania and New York. The usual measurement, however, is between 20 and 100 feet.

The deposits are massive in character, thus appearing to have been laid down with little interruption. The rock is highly cross bedded, a feature made more prominent by weathering. Texturally the Sharon member varies from a coarse conglomerate to a fine-grained sandstone. The chief cementing components are iron compounds and clay matter. The pebbles and sand grains are composed almost entirely of quartz and quartzite with a clear to milky color. The particles are well rounded and polished, thus showing the extent of abrasion from transportation.

The Sharon conglomerate, which is so massively and characteristically developed in northwestern Jackson and northeastern Pike counties, is feebly represented in western Vinton County. With the exception of a few thin, irregular lenses of sandstone found in southern Richland Township, the member is absent throughout the wide area in

which it should appear. It is wanting through lack of deposition, as the Mississippian rocks in this region remained as a land area until after these coarse sediments had been laid down elsewhere. The following record, taken north of Richland Furnace in Section 4, Richland Township, shows the character of the material and the position of the bed with reference to the Sciotoville clay and Vinton shale.

Pottsville formation	Ft.	In.
Shale, light.....	12	0
Ore, irregular, <i>Guinea Fowl</i>		4
Shale.....	1	10
Clay, flint, good.....	4	0
Clay, plastic, part covered } <i>Sciotoville</i>	4	0
Clay, red, "pink eye"....	6	0
Sandstone, light, clay-bonded.....	2	0
Covered.....	22	0
Sandstone, coarse-grained, <i>Sharon</i> conglomerate equivalent.....	8	0
Logan formation		
Shale, gray, <i>Vinton</i>	6	0
Covered.		

Local lenses of sandstone representing the Sharon member are also present along Pleasant Valley and Kelley Branch in the western part of Richland Township and along the ridges in the southeastern part of Harrison. The deposits vary from 1 to 20 feet in thickness and are sandstone and not conglomerate. They have not been utilized within the area.

SHARON CLAY

The Sharon clay lies directly below the Sharon or No. 1 coal. These beds are found in only one small area in Vinton County which is in the southern part of Section 29, Richland Township. The clay is thin, siliceous, and impure, and therefore has no value for ceramic purposes.

SHARON OR No. 1 COAL

Stratigraphy, extent, and value

The Sharon or No. 1 coal, locally known also as the Briar Hill, Mahoning Valley, Palmyra, Akron, Wadsworth, Massillon, and Jackson Shaft, owing to its presence with minable thickness in these localities, is the lowest coal bed in the Pottsville formation of Ohio and rests in most places on or only a few feet above the Sharon conglomerate. It lacks continuity in this State, being absent far more often than present. This is due to the fact that it was deposited only in the low basins that were eroded in the Mississippian floor at the close of this period.

The Sharon coal is absent in Vinton County with the exception of one small patch near drainage level in south central Section 29, Richland Township, where it has been mined in a small way for local use. The following measurements were taken in an old mine on the Barbee property:

	Fr.	In.
Sandstone, massive.....	5	0
Coal, cannel, hard.....	1	8
Coal, bituminous, hard, cannel nature } Sharon		5
Clay.....		0

The upper stratum varies in thickness from 7 to 8 inches and is a hard, dense, cannel coal. The lower bench expands from 1 foot to 1 foot 6 inches and is of a semi-cannel nature. The average thickness of the member is stated to be approximately 2 feet, and its position as nearly as could be determined is about 20 feet below the Sciotoville clay and only a few feet above the Logan shale. The bed is reported to be present also on the adjacent property to the east, but it was not exposed. Elsewhere in western Vinton County the Sharon coal appears to be wanting or to be at most only a few inches in thickness. The value of the known deposit is small as the bed is local in extent and as the coal is somewhat shaly. The main use is for a local supply of domestic fuel.

SHARON ORE

Locally in parts of Ohio a thin bed of iron ore, either kidney or blackband, is present directly on or not far above the Sharon coal. The member is of massive origin and bears an abundant fauna. It was not found in Vinton County but is present in many places in Jackson, Pike, and Scioto counties.

SCIOTOVILLE CLAY

Stratigraphy and extent

The Sciotoville clay is another lower Pottsville member which lacks continuity but which is recognized with a degree of certainty over a wide area. In Ohio it is present locally from Akron in Summit County to the Ohio River in Scioto County, and in Kentucky it extends southward with continuity and good thickness from the Ohio River in Greenup and Lewis counties, through Carter into Elliott and Brown. At present the important fields are near Scioto Furnace in Scioto County, Ohio, and near Olive Hill in Carter County, Kentucky. Where the lower members of the Pottsville formation are present, the normal position of the Sciotoville clay is, on the average, 20 to 40 feet above the Sharon coal and approximately the same dis-

tance below the Quakertown coal. Owing to the fact, however, that basal Pottsville strata are wanting in large areas, this clay may be absent, or if present, it may lie on or only a few feet above the Vinton sandstone, the Maxville limestone, or the Sharon conglomerate.

The Sciotoville clay is variable both in composition and in structure. It is represented by a variety of clays which are called flint, semi-flint, plastic, and "pink eye." The flint clay is hard, homogeneous, and non-plastic. It breaks in any direction with a conchoidal fracture and weathers down into sharp, angular fragments. The semi-flint clay has much the same characteristics as the flint clay, except that it is somewhat plastic and is marked with some slickensides. As the name suggests, the chief property of plastic clay is plasticity. It is usually marked with many slickensides and is easily reduced by weathering. The "pink eye" is simply a plastic clay which is mottled or stained with iron oxide pigments so that it has a pink color. These clays may be bedded in almost any order, although when all the varieties are present, the usual arrangement in ascending order is "pink eye," semi-flint, flint, and plastic. However, the four kinds are seldom present at one place, but any combination of the four may be expected.

In Vinton County deposits of Sciotoville clay are confined to Richland, Harrison, Eagle, and Jackson townships, and in general they appear to be small and uncertain. Plastic clay is the common material on the horizon but flint clay is occasionally present.

Richland Township.—In Richland Township the Sciotoville clay is due above drainage along Middle Fork, Riley Run, and Kelley Branch in the northwestern part; along Pleasant Valley, Burton Hollow, and Richland Hollow in the southwestern part; and along Little Raccoon Creek in the southeastern part. Owing to the pronounced disconformity at the base of the Pottsville formation, however, the member is absent far more often than present.

The Sciotoville clay was formerly mined in a small way on the Richland Furnace land near central Section 4. A composite record is given below:

Pottsville formation	Fe.	In.
Ore, <i>Lower Mercer</i>		3
Covered.....	45	0
Sandstone and covered.....	25	0
Shale and covered.....	25	0
Sandstone and covered.....	15	0
Covered.....	16	0
Shale, light.....	12	0
Ore, irregular, <i>Guinea Fowl</i>		4
Shale, gray.....	1	10

	Ft.	In.
Pottsville formation—Concluded		
Clay, flint, good.....	4	0
Clay, plastic, part covered } <i>Sciotoville</i>	4	0
Clay, red, "pink eye"....	6	0
Sandstone, light, clay-bonded.....	2	0
Covered.....	22	0
Sandstone, coarse-grained, <i>Sharon conglomerate</i> equivalent.....	8	0
Logan formation		
Shale, gray, <i>Vinton</i>	6	0
Covered.		

The flint clay is of good quality and the underlying plastic clay of fair purity. In northeastern Section 33, the Sciotoville clay was exposed just above water level near where the road to the ridge north leaves the stream. At least 5 feet of semi-flint clay of fair quality is present. Its elevation is about 770 feet and its position nearly 100 feet below the Lower Mercer or No. 3 coal. The member is reported to be present at other places also in this vicinity. In the east fork of Burton Hollow near central Section 33, flint clay underlain by "pink eye" outcrops just above the stream bed. The thickness was not determined as the exposure is poor. The flint clay is hard, light-colored, and pure. Along the stream in south central Section 29, on the Barbee property, the Sciotoville clay outcrops near the level of the township road and at an elevation of about 770 feet. The following measurements were obtained:

	Ft.	In.
Shale, gray.....	2	0
Shale, dark, carbonaceous.....		4
Coal, weathered, <i>Huckleberry</i>		6
Clay, plastic, very siliceous, <i>Huckleberry</i>	1	7
Shale, dark, carbonaceous, very siliceous.....	1	4
Clay, flint, plant-marked, good } <i>Sciotoville</i>	1	6
Covered.....	5	7
Clay, "pink eye".....	4	0
Shale, shaly sandstone, and covered.....	12	0

The flint clay at this place is of good quality and is reported to be 3 to 4 feet thick. Along the road at the head of the hollow in northeastern Section 30, the Sciotoville member is present at an elevation of about 800 feet and is represented by 2 feet 6 inches of very siliceous, plastic clay. Its position is 96 feet below the Lower Mercer coal and about 20 feet above the Vinton shale. Along the road near the forks of Little Raccoon Creek in southeastern Section 23, the Sciotoville member appears just above drainage at an elevation of 750 feet. The record obtained is given below:

	Ft.	In.
Sandstone, ferruginous, hard.....	2	0
Ore, siliceous, <i>Guinea Fowl</i>		4

	Ft.	In.
Shale, dark, part covered.....	14	0
Clay, flint, siliceous, <i>Sciotoville</i>	1	4
Covered to stream bed.....	4	6

The Sciotoville member appears to be poorly represented along Middle Fork, Riley Run, and Kelley Branch in northwestern Richland Township. It is absent over most of the area and where present is thin, siliceous, and impure.

Harrison Township.—In Harrison Township basal Pottsville members are found near the summits of the ridges in the eastern part. The Sciotoville member is only locally present and is usually represented by impure plastic clay rather than by high-grade flint clays. On the W. H. Doles farm in south central Section 36, a small quantity of flint clay was mined by stripping. The clay is of good quality but the deposit appears to be only a local lens. The position of the bed is on or only a few feet above the Sharon conglomerate, at this place represented by about 20 feet of coarse-grained sandstone. The following record, taken along the ridge road in east central Section 35, shows the position of the Sciotoville member with reference to other beds in the Pottsville and Logan formations:

	Ft.	In.
Pottsville formation		
Sandstone, shaly.....	14	0
Ore, irregular, siliceous, <i>Guinea Fowl</i>		8
Shale, siliceous, gray.....	1	0
Clay, plastic, light gray, siliceous, <i>Sciotoville</i>	10	0
Shale, light, very siliceous.....	12	0
Sandstone, light, part shaly.....	11	0
Sandstone, argillaceous, micaceous.....	15	0
Shale, sandstone and covered.....	17	0
Logan formation		
Sandstone, argillaceous, yellowish with shaly layers.....	17	0
Shale, soft, bluish-gray.....		
	10	0

Siliceous, plastic clay was also observed on the horizon at a few places in sections 25, 26, and 23, and in addition thick deposits of "pink eye" clay are locally present. The following record, taken near the forks of the road in east central Section 27, is representative of this phase:

	Ft.	In.
Sandstone.....	1	0
Clay, plastic, light.....	1	6
Clay, plastic, very red, "pink eye".....	5	2
Sandstone, irregular, ganister.....	2	8
Clay, plastic, "pink eye".....		8
Sandstone, light, ganister.....		0
Clay, plastic, light.....		0
Covered.....	3	0
Forks of road, altitude 935 feet.		

The ganister associated with the clay at this place is hard, dense, and argillaceous, and is very similar in character to that found with the Sciotoville member in the Scioto Furnace field of Scioto County. The beds are generally thin and are uncertain in extent and thickness. The "pink eye" clay is highly colored due to severe weathering.

Eagle Township.—No deposits of Sciotoville clay of merit were observed along the few ridges in the eastern part of Eagle Township on which Pottsville rocks are present. The scattered exposures which are found show only siliceous, plastic clay from 3 to 5 feet thick.

Jackson Township.—Basal Pottsville members, including the Sharon conglomerate, Sharon coal, and Sciotoville clay, appear to be wanting through lack of deposition throughout most of Jackson Township. At a few places the Sciotoville member is marked by a siliceous, plastic clay or by "pink eye." Flint clay of good quality was found only in central Section 26, where it was exposed in a ravine at an elevation of 935 feet. The bed is more than 3 feet thick and the material very pure. Its position is about 30 feet above the Logan formation.

Economic value

The deposits of Sciotoville clay in Vinton County appear to be too local in extent and too variable in character to be utilized as the basis for large ceramic operations. The area of most promise is in Richland Township and extends from Richland Furnace in Section 4 northward to Pleasant Valley in Section 29. It should be thoroughly tested by the core drill, however, as the outcrop indications are that the deposits are small and widely isolated. The flint clay exposed in this locality is of good quality, well fitted for making high-heat duty refractory ware. The plastic clay of the Sciotoville member found here and elsewhere in the county is of poor quality as it is generally very siliceous, in many places ferruginous, and ranks not better than a building brick clay.

ANTHONY COAL

Stratigraphy, extent, and value

The Anthony coal was named in 1870 by E. B. Andrews from a deposit on the farm of Samuel Anthony in Section 7, Coal Township, Jackson County. Its position is directly above the Sciotoville clay and about midway in the interval between the Sharon and Quakertown coals, and its distribution is coextensive with that of the Sciotoville clay. The bed is generally thin, averaging about 4 inches and in few places expanding to more than 1 foot. In places it is represented only by a soot streak or by a few inches of dark, coaly clay. The Anthony

member varies in quality from a rather pure fuel to a bony, carbonaceous shale and also from ordinary bituminous to dense cannel coal. The overlying shales frequently contain brackish water fossils in abundance.

In Vinton County the Anthony coal outcrops locally in Richland, Harrison, Eagle, and Jackson townships, but it is everywhere thin and generally impure. The usual thickness is about 4 inches. The following record, taken at the forks of the road in central Section 25, Richland Township, shows the Anthony coal above normal in both thickness and purity:

	Ft.	In.
Ore, siliceous, <i>Guinea Fowl</i>		6
Shale and covered.....	8	0
Coal, fair, <i>Anthony</i>		8
Clay, siliceous and covered.....	2	0
Road forks, altitude 733 feet.		

In the southwestern part of this township the member is usually represented by a soot streak or by a few inches of carbonaceous shale. The same is true in Eagle and Jackson townships. In Vinton County, the Anthony coal has no economic value but is of interest only for its stratigraphic relations.

"HUCKLEBERRY" COAL AND CLAY

The name "Huckleberry" has been applied locally, both in the Olive Hill field of Kentucky and in the Sciotoville field of Ohio, to a bed of clay and to its thin overlying coal, the positions of which are not far above the Sciotoville clay and Anthony coal. Such deposits are lenticular in character and very patchy and uncertain in extent. These members were observed at only a few places in Vinton County and have no value worthy of consideration.

GUINEA FOWL ORE

Stratigraphy, extent, and value

An iron ore to which the name Guinea Fowl was applied by the miners who worked such deposits for Scioto Furnace, operated from 1829 to 1892 in Bloom Township, Scioto County, is occasionally present in the lower part of the Pottsville formation of southern Ohio. It represents an ore horizon rather than an ore stratum, as the deposits occur at various positions in a shale stratum and are widely scattered. The position of the ore may change from 1 to as much as 20 feet above the Anthony coal, but the usual interval is between 5 and 15 feet. The member varies in thickness from 1 inch to 2 feet but averages nearly 6 inches. It may be represented by a single ore stratum or by

two or even three benches separated by shale. The Guinea Fowl ore is locally present in Richland, Harrison, Eagle, and Jackson townships.

At the forks of the road east of the Darby School in Section 35, Richland Township, the Guinea Fowl ore, 4 to 6 inches thick, is exposed at an elevation of 765 feet. Its position is nearly 120 feet below the Lower Mercer limestone. Small quantities of this ore were formerly mined by stripping near the forks of the road in central Section 25, where the bed is about 6 inches thick and approximately 8 feet above the Anthony coal. The following record, taken near the forks of Little Raccoon Creek in southeastern Section 23, shows its position with reference to the Sciotoville clay:

	Ft.	In.
Sandstone, ferruginous, hard.....	2	0
Ore, <i>Guinea Fowl</i> , altitude 765 feet.....		4
Shale, dark, part covered.....	14	0
Clay, flint, <i>Sciotoville</i>	1	4
Covered.....	4	6
Stream bed.		

The ore, a siliceous limonite, is made up of small ore kidneys cemented by iron oxides into a firm mass. The weathered faces in many cases have the appearance of a conglomerate of ore nodules. The member was also observed at other places in central and western Richland Township.

The Guinea Fowl ore is moderately persistent and has fair thickness in eastern Harrison Township. The following record, taken on the property of William Scott in southeastern Section 24, shows the position of the ore with reference to the Quakertown coal:

	Ft.	In.
Pottsville formation		
Shale, dark.....	3	0
Coal.....	1	10
Shale.....	} <i>Quakertown</i>	$\frac{1}{4}$
Coal.....		$3\frac{1}{2}$
Clay, siliceous.....	2	0
Covered.....	7	0
Shale.....	5	0
Ore, irregular, fossiliferous, <i>Guinea Fowl</i>		4
Shale.....		6
Logan formation		
Shale, gray, siliceous.....	10	0

Along the road that leads from the head of the hollow to the ridge east in southeastern Section 24, the Guinea Fowl ore was well exposed at an elevation of 890 feet. The ore is siliceous and sparingly fossiliferous. Its thickness here is 1 foot 4 inches and its position 37 feet above the Allensville conglomerate and 45 feet below the Bear Run coal. An outcrop of this member at an elevation of 850 feet was ob-

served along the road in the east central part of Section 35. The bed is 8 inches thick and lies only a few feet above the Sciotoville clay. The Guinea Fowl member is locally made up of two or more ore benches as shown in the following measurements obtained along the ridge road near the forks in northeastern Section 26:

	Ft.	In.
Forks of road, elevation 950 feet.		
Shale, gray.....	6	0
Shale, dark, siliceous.....	5	0
Shale, black, fissile, <i>Bear Run</i> coal horizon.....	6	0
Shale, gray, parts covered.....	15	0
Shale, soft.....	1	0
Coal, rotten, <i>Quakertown</i>	2	0
Shale, dark, carbonaceous.....	1	6
Clay, light, siliceous.....	3	8
Clay, dark, shaly.....	1	0
Clay shale, light to dark.....	3	6
Shale, dark.....	2	6
Ore, kidney.....		1
Shale, dark.....		10
Ore, siliceous, blackband.....		7
Shale, dark.....	3	4
Ore, kidney.....		3
Shale, dark.....	1	0

Guinea Fowl

The Guinea Fowl member was also observed on a knob of the ridge near the road forks in southeastern Section 27. The bed is 4 to 6 inches thick and siliceous in character. It bears a few fossils which are not well preserved. Its position is directly above the Anthony coal and 73 feet above the Allensville conglomerate.

In Eagle Township the lower Pottsville members are poorly represented, some through lack of deposition and others through replacement by the thick Massillon sandstone. The Guinea Fowl ore with good development was observed at only one place which is on the high knob north of High Hill School in southeastern Section 27. The record secured is given below:

	Ft.	In.
Pottsville formation		
Ore, siliceous, sparingly fossiliferous.....		7
Shale and covered.....	3	11
Ore, made up of small concretions about pea size, elevation 1,030 feet.....		8
Covered.....	9	0
Logan formation		
Shale and sandstone.....	12	0
Sandstone, shaly.....	15	0
Sandstone, shale, and covered.....	27	0
Shale and covered.....	32	0
Conglomerate, <i>Allensville</i>	1	8

At this place the upper layer of ore is sparingly fossiliferous but the specimens are mostly fragmental. The Guinea Fowl ore is poorly developed in Jackson Township.

This ore, even in the days of the charcoal furnaces, was of little value in Vinton County. It has fair thickness and extent but is lacking in quality as it is everywhere siliceous. In this locality the bed was mined at only a few places and there only in a small way, and its use was confined to Richland Furnace. At present the member has no economic value worthy of consideration.

QUAKERTOWN CLAY

Stratigraphy and extent

The Quakertown clay lies below the Quakertown or No. 2 coal the position of which is normally 90 to 110 feet below the Lower Mercer limestone and 25 to 40 feet above the Sciotoville clay. In Vinton County the member is present at the surface in Richland, Harrison, Eagle, Jackson, and Swan townships and has been reached by shafting in Elk, Madison, and Clinton townships. The bed varies from 1 to 5 feet in thickness but averages only about 2 feet 6 inches. It is a plastic clay which is generally very siliceous and in many cases contaminated with small, ferruginous concretions. Locally ganister or clay-bonded sandstone is present below or interbedded in the clay. The thickness of this rock ranges from a few inches to several feet. Neither the clay nor the ganister is of high grade, hence they will be treated briefly.

In Swan Township the Quakertown clay is present at or not far above drainage along Brushy Fork from Creola to northern Section 27; along the stream west of Creola in sections 33, 29, and 30; and along Siverly Creek in sections 28, 21, 20, 19, 18, and 7. Where observed the clay is thin, from 1 to 4 feet, and very siliceous. On account of the dip of the rocks east and south, Quakertown members are present near the ridge summits in western Jackson Township and not far above the valley floors in the eastern part. In the few areas where the coal is present the associated clay is thin, siliceous, and impure. For like reasons the bed has no value in Eagle Township. It has fair development in eastern Harrison Township but shows little improvement in quality. The following record, taken in north central Section 26, is approximately representative:

	Ft.	In.
Shales.....	16	0
Coal, weathered, <i>Quakertown</i>	2	0
Shale, dark, carbonaceous.....	1	6
Clay, plastic, siliceous, light.....	3	8
Clay, dark, shaly.....	1	0
} <i>Quakertown</i>		

The Quakertown clay, where present in Richland Township, has no qualities to recommend its use for ceramic purposes. The bed is everywhere thin and the material impure. In Elk Township this coal and clay have been reached by shafting at Elk Fork in Section 9 and at Elko in Section 23. They appear just above drainage also at one place which is along Elk Fork in eastern Section 8. In Elk Fork Mine No. 1 of the Elk Fork Coal Co., the following record was secured:

	Ft.	In.
Shale.....	20	0
Coal, <i>Quakertown</i>	2	8
Clay, siliceous, dark, irregular.....	2	0
Ganister, hard, irregular.....	3	0

The thickness of the coal in this mine varies from 2 feet 2 inches to 3 feet 8 inches, that of the clay from 6 inches to 4 feet, and that of the ganister from 2 to 10 feet. The ganister is present in large quantities and was sampled for testing. (See below.) Clay and ganister of similar thickness and quality are also present in the old Elko mine.

Economic value

In Vinton County the Quakertown is everywhere a siliceous, plastic clay of low refractory quality and in places it contains many concretions of ferruginous matter which further impair its value. Its working and drying properties are fair. The ganister on this horizon is hard, light colored, and fine grained, rather free from visible impurities. It consists principally of quartz sand which is bonded with a small quantity of clay. The plasticity is low.

Tests of ganister of Quakertown member in mine of Elk Fork Coal Co., Elk Fork, Vinton County:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	.36	K ₂ O	.202	Al ₂ O ₃	1.00 {
Ignition loss.....	3.53	Na ₂ O	.059		
Silica, SiO ₂	80.30	CaO	.028		
Alumina, Al ₂ O ₃	9.23	MgO	.010		
Ferric oxide, Fe ₂ O ₃	3.40	FeO	.331		
Lime, CaO.....	.26	MnO	.002		
Magnesia, MgO.....	.09				
Titanic oxide, TiO ₂	1.00	RO	.632		
Phosphorus pentoxide, P ₂ O ₅	.05				
Sodium oxide, Na ₂ O.....	.54				
Potassium oxide, K ₂ O.....	1.86				
Manganous oxide, MnO.....	.02				
Sulphur, S.....	.02				
Total carbon, C.....	.35				
Inorganic carbon.....	.29				

Physical tests

Working properties: Very short, lacks plasticity, coarse, grainy, molds poorly.

Tempering water.....	16.37 per cent.
Drying linear shrinkage.....	0.92 per cent.
Drying volume shrinkage.....	2.79 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 07	....	....	25.95	Cream
" 03	1.32	3.91	30.15	Light buff
" 2	....	....	28.32	Medium buff
" 5	0.73	2.16	22.63	Medium buff
" 6	2.15	6.30	16.32	Gray speckled
" 7	2.56	7.48	14.70	Gray speckled
" 10	1.91	5.61	11.49	Gray speckled
" 12	....	....	5.14	Gray speckled

Overburning temperature: Cone 10 (1,330° C. or 2,426° F.).

Best apparent burning range: Cones 5 to 7 (1,230° C. to 1,270° C. or 2,246° F. to 2,318° F.).

Total linear shrinkage at cone 7: 3.48 per cent.

Deformation temperature: Cone 17 (1,470° C. or 2,678° F.).

Possibilities: Owing to its siliceous nature and very low shrinkage, it would appear to be useful for lining steel ladles.

QUAKERTOWN OR No. 2 COAL

Stratigraphy and extent

The Quakertown coal was named in 1879 by I. C. White for exposures on Quakertown Run, near the Ohio-Pennsylvania line in Mahoning Township, Lawrence County, Pennsylvania, where it was worked in a small way for local use. At this place its position is just below the massive Upper Connoquenessing sandstone. The Quakertown member extends with many wants and usually in an impoverished condition across Ohio from Mahoning County on the north to Scioto County on the south. In this State the bed is best developed in Jackson County where it was brought into prominence in 1872 through the efforts of H. S. Bundy and where it has been mined steadily since that date. It has been worked also in a small way for many years in Vinton County. In these fields the member is generally known to the trade as the Wellston, the Jackson Hill, or the Elk Fork coal.

The position of the Quakertown coal is 60 to 80 feet above the Sharon coal, 25 to 40 feet above the Sciotoville clay, and 90 to 110 feet below the Lower Mercer limestone, which are the most prominent benches for reference. Further, it is commonly overlain and in many places replaced by the thick Massillon or Connoquenessing sandstone. Where the Sharon conglomerate has full thickness, the Quakertown member lies near the middle of the Pottsville formation. In many localities, however, the older Pottsville beds are absent, in which case this coal lies not far above the Waverly sandstone.

In Vinton County the Quakertown coal is due above drainage in eastern Eagle, Jackson, western Swan, eastern Harrison, western and central Richland, and central Elk townships and has been reached by shafting in northern and eastern Elk and southwestern Madison townships. Although the field is large, only in small areas in Jackson, Richland, Harrison, Elk, and Madison townships, has the bed sufficient thickness for mining. Future drilling may develop other valuable areas. The Quakertown coal varies in thickness from a soot streak to 4 feet; in the best parts of the field usually between 2 feet and 3 feet 6 inches. It is everywhere a bituminous coal with an occasional layer of a few inches of a cannel interbedded in the stratum.

Harrison Township.—Quakertown coal has been mined in a small way for many years along the ridges in southeastern Harrison Township. The main field is confined to sections 23, 24, 25, and 26, where the average thickness of the bed is nearly 2 feet 3 inches. The quality of the fuel is excellent. In a mine on the farm of Eli Clark in west central Section 24, the following record was secured:

	Ft.	In.
Sandstone, massive.		
Shale, dark, good roof.....	10	0
Coal, <i>Quakertown</i> , elevation 930 feet.....	2	1
Shale, black.....		8
Clay, siliceous.		

The bed varies from 1 foot 8 inches to 2 feet 6 inches in thickness. The coal is bright, clean, and low in pyrite. The bed is very steady in this locality and was formerly mined west of this in Section 23. In the southeastern corner of Section 24, a wagon mine is operated on the property of William Scott. Measurements obtained are given below:

	Ft.	In.
Shale, dark, good roof.....	3	0
Coal.....	1	10
Shale, black.....	} <i>Quakertown</i> , elevation 905 feet	
Coal.....		
Clay, siliceous.....	2	0

The coal expands from 1 foot 8 inches to 2 feet 6 inches but averages 2 feet 2 inches. The black shale parting is only locally present. Several small mines were formerly worked along the road in east central Section 25. The elevation of the bed is 880 feet and its position nearly 80 feet below the Lower Mercer coal and 60 feet above the Logan shales. North of this in the mine of C. C. Dozer, the following measurements were obtained and a sample cut for analysis. (See page 91.)

	Ft.	In.
Shale, dark gray, good roof.....	3	0
Shale, black.....		1
Coal, good, sampled, <i>Quakertown</i> , elevation 870 feet.....	2	1 $\frac{1}{4}$
Shale, black.....		3
Clay, siliceous.....	2	0

The member is very constant in thickness, averaging about 2 feet 2 inches. The fuel is of excellent quality, much resembling that in the Coalton field of Jackson County. In northeastern Section 26, the *Quakertown* member is only locally present, its absence being due both to lack of deposition and to replacement by sandstone. In the southeastern part of the area the bed is mined for the local trade on the farm of L. C. Boch. A section in the mine is given below:

	Ft.	In.
Shale, gray.....	5	0
Coal, <i>Quakertown</i> , elevation 885 feet.....	2	4
Shale, dark.....		4
Clay, dark, siliceous.....	1	6

Locally in this mine the coal thickens to 2 feet 6 inches. The bed has been worked at other places near by and also on the farm of Simon Collins in central Section 26, where a measurement in an old entry shows 2 feet 4 inches of good coal. The elevation of the member is 890 feet and its position 70 feet above the Logan formation.

Richland Township.—The *Quakertown* coal is thin or wanting in most of Richland Township and in only a few places has it been mined even in a small way. Formerly it was worked for shipment and local use in Section 6, south, but the area is now largely exhausted. The member is reported to be about 2 feet 6 inches thick and the fuel of good quality. Its position is close to 880 feet above tide. In southwestern Section 30, the Lower Mercer coal is mined for local trade and the *Quakertown* bed has been opened along the outcrop. Measurements obtained on the Barbee property are given below:

	Ft.	In.
Shale, black.....	2	0
Coal and parting, <i>Lower Mercer</i>	3	9
Clay, shale, sandstone, and covered.....	78	8

	Ft.	In.
Coal, <i>Quakertown</i> , elevation 860 feet.....	1	4
Shale, dark.....		6
Clay, siliceous.....	2	0

In this locality the interval between the coals varies from 65 to 85 feet. East of this in sections 29 and 32, the *Quakertown* coal is thin or it is completely replaced by the *Massillon* sandstone, the position of which with reference to this member is shown on the following record secured along the road in northwestern Section 29:

	Ft.	In.
Top of ridge.....		
Covered.....	3	0
Coal smut, <i>Middle Mercer</i>		3
Clay, shale, and covered.....	6	9
Coal smut in clay, <i>Flint Ridge</i>		3
Clay.....	1	0
Shale and covered.....	37	9
Coal blossom, <i>Lower Mercer</i>	2	0
Clay, plastic, light.....	2	0
Shale and covered.....	36	0
Sandstone, <i>Massillon</i>	27	0
Coal, reported thickness, <i>Quakertown</i> , elevation 835 feet.....	1	8

In the vicinity of Richland Furnace the *Quakertown* coal is reported to be present locally and to vary from a few inches to 2 feet in thickness. Along Little Raccoon Creek in the eastern part of the area, the member is of no importance even for local needs.

Eagle Township.—In Eagle Township, lower *Pottsville* rocks are present only along the ridges in sections 11, 12, 14, 25, 26, and 36. No deposits of workable coal are known within the area, the *Quakertown* bed being replaced by *Massillon* sandstone.

Jackson Township.—*Quakertown* coal is widely distributed in Jackson Township but is lacking in continuity and development. Where present the member is found only a few feet above the *Logan* shales. It lies near the summits of the main ridges in the western part of the area but descends close to or even below drainage level in the eastern part. This coal is best represented in sections 5, 8, 13, 17, 22, and 29, where it has helped to supply local needs.

Near the Chestnut Grove Church in Section 5, the *Quakertown* coal has been worked in a desultory way for many years. The thickness of the bed varies from 1 foot or less to 4 feet or more but averages about 3 feet. The following record, secured on the land of William Walton, is about representative of the stratigraphic features:

	Ft.	In.
Ore, kidney, <i>Lower Mercer</i>		3
Clay, shale, and covered.....	10	0
Shale and covered.....	11	0

	Ft.	In.
Sandstone, massive, parts covered.....	40	0
Covered.....	40	6
Coal, weathered, <i>Bear Run</i>	1	0
Clay, impure.....	1	6
Sandstone, shaly.....	5	0
Shale, dark.....		8
Coal, hard, good.....	1	7
Coal, bony.....		3
Coal, hard, good.....		0
Sandstone, argillaceous.....	1	0
Covered.....		

} *Quakertown*, elevation 980 feet

The maximum thickness reported in this locality is 4 feet 2 inches. Normally the bed has no regular parting or bone bands. Near by this member was examined by Andrews in 1870 and the measurements recorded are given below:¹ (See analysis, page 92.)

	Ft.	In.
Sandstone, shaly.....	8	0
Sandstone.....	3	0
Clay shales.....	10	0
Coal [<i>Quakertown</i>].....	2	10
Clay, plastic.....	3	0
Covered.....	2	0
Shale and sandstone [<i>Logan</i>].....	120	0
Conglomerate.....		

The terms in brackets in the above section were supplied by the writer.

Along the ridges in southern Section 8 and in northern Section 17, the *Quakertown* member was formerly mined at a few places. In a prospect opening on land of Thomas Davis, which is located in north central Section 17, the following measurements were secured:

	Ft.	In.
Sandstone, coarse-grained.....	2	0
Shale with sandstone layers.....	1	7
Ore and sandstone.....		2
Shale, carbonaceous.....		5
Coal, good, <i>Quakertown</i> , elevation 970 feet.....	2	10
Clay, siliceous.....	1	0

The bed is free from clay or bone partings. This coal was formerly worked also near the forks of the road in central Section 29 where it is reported to vary in thickness from a few inches to 2 feet 6 inches. The area appears to be small as the member is replaced by sandstone. The *Quakertown* coal appears again along the stream in central Section 13 where the thickness reported is about 2 feet.

¹Geol. Survey Ohio, Report of Progress, 1870, p. 97.

Swan Township.—In Swan Township the Quakertown coal is above drainage along Siverly Creek in sections 7, 18, 19, 20, 21, and 28; along Brushy Fork in sections 27 and 34; and along the tributary west of Creola in sections 33, 29, and 30. The member, however, is poorly represented, being generally thin and in many cases completely wanting. It has been mined but little even for local use.

Just east of the depot at Creola, on land of Mrs. E. J. Herwick, the Quakertown coal lies just above drainage level and has been prospected by a small drift. The elevation of the bed is about 725 feet and its position nearly 110 feet below the Upper Mercer ore and flint. The member at this place is reported to consist of two coal benches, each about 1 foot thick, separated by a clay parting, also measuring nearly 1 foot. About one-fourth mile west of Creola and north of the road, the following composite section was secured:

Pottsville formation	Ft.	In.
Ore, <i>Upper Mercer</i>		4
Shale.....	1	8
Coal blossom, <i>Bedford</i>		4
Clay and covered.....	6	8
Shale, shaly sandstone, and covered.....	31	0
Ore, <i>Lower Mercer</i>		3
Clay, plastic.....	3	0
Shale and covered.....	18	9
Coal blossom, <i>Lower Mercer</i>		6
Clay, impure.....	1	6
Covered.....	18	0
Sandstone, massive, part covered; <i>Massillon</i>	53	0
Coal, <i>Quakertown</i> , elevation 760 feet.....		6
Clay and covered.....	2	0
Shale.....	3	0
Logan formation		
Sandstone, shaly, <i>Vinton</i>	15	0

The Quakertown member at this place is thus found to lie only 5 feet above the Vinton sandstone and 95 feet below the Lower Mercer ore. The coal in this area is reported to vary from a few inches to 2 feet in thickness and to be of good quality. Locally it is replaced by the massive overlying Massillon sandstone. Along the stream near the forks of the road in central Section 30, the Quakertown bed again appears just above drainage at an elevation of about 820 feet. The member where exposed measures from 5 inches to 1 foot 2 inches in thickness but near by it is reported to expand to 1 foot 6 inches. This variation in thickness is due to replacement of the upper part by sandstone. The fuel is of excellent quality, being hard, bright, and free from bone. Along Siverly Creek in Section 21, Quakertown coal is present from 5 to 20 feet above the Logan formation. The

bed is generally thin, only a few inches thick, but locally it expands to nearly 2 feet.

Elk Township.—In Vinton County the Quakertown coal is of most importance in Elk Township where it has been mined in a small way for more than 60 years. The area is yet far from being exhausted but the coal is uncertain in thickness and in extent. The bed appears at the surface at only two places which are along Elk Fork in eastern Section 8 and along a tributary of this stream in northeastern Section 16. It is mined by shafting at Elk Fork and was formerly worked by this method at Elko or Vinton in Section 23. The bed, although subject to considerable variation in thickness, retains its high quality throughout the field.

The No. 1 mine of the Elk Fork Coal Company at Elk Fork was opened by C. K. Davis in 1900 and is still in operation. The bed expands from 1 foot 6 inches to 4 feet but averages about 3 feet 4 inches. It lies only a few feet above the Logan sandstone and is subject to rolls which cause the coal to have a maximum variation in level of nearly 20 feet and which therefore make mining somewhat difficult. The coal is thickest in the troughs and thinnest on the crests. The shaft is 90 feet deep. An average section of the mine is given below:

	Ft.	In.
Shale, siliceous.....	10	0
Coal, <i>Quakertown</i>	3	4
Clay, siliceous, light.....	4	6
Shale, dark.....	6	0

The coal bed is free from clay or shale partings and from pyrite concretions. The quality is much the same from top to bottom. For a thin bed the stratum mines easily and has a good roof and floor. A small quantity of Quakertown coal was mined by stripping with a steam shovel along the stream in the northwestern corner of Section 15, where the bed varies in thickness from 1 foot 10 inches to 2 feet 6 inches. Under cover it is reported to increase to as much as 3 feet. This member also appears at the level of Elk Fork in eastern Section 8 where it is mined by drifting on the property of John Bancroft. A composite section at this place shows the position of the Quakertown member with respect to other well known strata higher in the geological column:

	Ft.	In.
Shale, gray.....	8	4
Shale, gray, fossiliferous, <i>Putnam Hill</i>	2	0
Coal blossom, <i>Brookville</i>	2	8
Clay, light, plastic.....	3	0
Sandstone, argillaceous, light.....	10	0
Covered.....	5	9
Ore, <i>Upper Mercer</i>		3

	Ft.	In.
Shale and shaly sandstone.....	14	7
Clay shale, dark.....	1	0
Coal, blocky, <i>Upper Mercer</i>		5
Clay, dark, siliceous.....	2	0
Shale and covered.....	6	4
Ore, siliceous.....		7
Shale, gray, part siliceous.....	18	1
Shale, fossiliferous, <i>Lower Mercer</i>	1	0
Clay, light, siliceous.....	1	6
Shale, gray.....	2	6
Clay, light, shaly.....	2	0
Shale, gray, siliceous.....	10	0
Shale, dark, with thin coal bands, <i>Lower Mercer</i>		8
Clay, impure.....	1	0
Shale, gray, part siliceous.....	7	4
Sandstone, soft.....	10	0
Sandstone and covered.....	19	0
Clay, light, plastic.....	2	0
Covered.....	16	4
Sandstone, hard.....	1	0
Shale, gray.....	12	8
Coal, <i>Bear Run</i>	1	4
Clay, impure.....		6
Shale, gray, siliceous.....	12	0
Coal, cannel, pyritic.....	} <i>Quakertown</i>, elevation 730 feet, all sampled for analysis	$\frac{1}{2}$
Coal, approaching cannel.....		5
Coal, hard, bright.....		$10\frac{1}{4}$
Coal, brittle.....		$8\frac{1}{2}$
Clay, siliceous.....	1	0

The position of the Quakertown coal at this place is thus 16 feet below Bear Run coal, 103 feet below Lower Mercer limestone, 147 feet below Upper Mercer ore, and 166 feet below Brookville coal, which intervals are not greatly different from what they are in the large field of Quakertown coal in Jackson County. In the mine on the Bancroft farm, the coal is very steady in thickness and uniform in quality. It is bright, brittle, and clean and was sampled for analysis. (See page 91.) Near by coal was formerly stripped from the stream bed for local use. The thickness given by Ballantine is 2 feet 7 inches.¹

At Vinton or Elko in Section 23, Quakertown coal was mined by shafting for railroad shipment for many years. The mine is now abandoned but much good coal is reported in adjacent areas. (See analysis, page 92.) The Albert Pierce farm in Section 25 was tested by Jerry Morrow of Wellston with the core drill. The results of 16 tests show that the bed is steady throughout the tract and has an average thickness of 3 feet. A representative record furnished by Mr. Morrow is given below:

¹Geol. Survey Ohio, Report of Progress, 1870, p. 105.

	Ft.	In.
Surface.....	10	0
Sandstone.....	12	0
Coal.....		3
Sandstone.....	40	0
Shale.....	15	0
Coal, <i>Lower Mercer</i>	1	6
Shale, sandy.....	34	0
Coal, <i>Bear Run</i> ?.....		11
Shale, sandy.....	18	0
Shale.....	11	0
Coal, <i>Quakertown</i>	3	3
Clay.....		6

The quality of the coal is stated by Mr. Morrow to be the same as that in the old Elko mine which ranked with the best in the Jackson County field. Future testing may extend the field both northward and eastward.

Madison Township.—In Madison Township the Quakertown coal was reached by a shaft at Vinton Furnace and by the core drill at a number of places in this vicinity. The deposits are reported to be patchy in character and uneven in elevation. The thickness varies from 1 foot to 3 feet 6 inches. The record of the shaft as given by Ballantine is as follows:¹

	Ft.	In.
Limestone, <i>Vanport</i>		
Covered.....	5	0
Coal.....		9
Shale.....		8
Coal.....	1	2
Covered.....	65	0
Coal [<i>Brookville</i>].....	2	0
Top of shaft, elevation 680 feet		
Soil, gravel, and clay.....	20	0
Shale, blue.....	40	0
Sandstone.....	7	0
Coal.....		3
Shale, black.....	11	6
Sandstones and shales.....	30	0
Flint, black?.....	1	6
Sandstones and shales.....	31	0
Coal.....		2
Clay.....	1	3
Coal.....		4
Sandstones and shales.....	23	8
Clay shale.....	18	0
Coal.....	1	3
Clay.....		3
Coal.....	1	4

¹Geol. Survey Ohio, Report of Progress, 1870, p. 114.

The terms in brackets were supplied by the writer.

The thickness of the coal in this old shaft mine is reported to vary from 2 feet 6 inches to 3 feet 6 inches. The area exhausted by mining is small. The Quakertown coal at this place is 187 feet below the Brookville coal which normally would place it about 100 feet below the Lower Mercer limestone, its position in Jackson County and also to the west in Vinton County. (See analysis, page 92.)

Economic value

The area of Quakertown coal in Vinton County with sufficient thickness for profitable mining is difficult to estimate as the bed is so erratic in thickness, in so many places replaced by sandstone, and so little prospected by the core drill under deep cover. At most, the fields are probably not sufficiently extensive to influence mining on a large scale. The deposits of most value are under cover in the central part of the county where the member has been mined for many years and where other areas of good coal are known through core drilling. This field as outlined has an area of more than 10 square miles in which, however, only patches have a thickness of 2 feet 6 inches or more. Along the outcrop in the western part of the county, deposits of Quakertown coal even 2 feet or more in thickness are small and scattered. The combined area of workable coal in the western field is not in excess of 5 square miles of which a small part has been exhausted.

The quality of the Quakertown coal ranks it as one of the finest domestic coals in this State and on a par with the best of those in West Virginia and Pennsylvania. Its merit is such that it has long had a wide reputation in western and northern markets and has commanded the highest prices. With few exceptions, the bed is free from clay and shale partings and from pyrite concretions and bands. It mines clean and discolors but little on standing. It belongs to the free-burning class of coals and on account of its high content of volatile matter it burns freely from the time ignited until it is consumed. Its heating value and lasting quality are fair. This coal produces but little smoke and practically no soot. Owing to its purity the coal is somewhat tender and therefore does not stand handling and shipping well. The Quakertown is not a coking coal and in the raw state is too free burning to give the best results in the blast furnace. It is, however, one of the very best coals in Ohio for ceramic products as it burns freely with a long flame, which, impinging on the face of the ware, produces a clear bright color and a thorough bonding of the components. It has a good reputation also for steaming and general heating purposes as the calorific value is above the average and as the ash is low and clinkers but little. The following analyses are representative.

The Quakertown coal on the property of C. C. Dozer, located in Section 25, Harrison Township, was sampled in June, 1925, at the head of the entry about 500 feet from the mine mouth. The coal, hard and bright, is free from shale partings and pyrite lenses. The sample was taken under good conditions and is representative of the bed in this locality:¹

<i>Ultimate analysis</i>			<i>Proximate analysis</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	67.35	76.00	Moisture.....	11.38	....
Hydrogen.....	5.78	5.10	Volatile matter.....	38.79	43.77
Oxygen.....	20.39	11.58	Fixed carbon.....	45.73	51.60
Nitrogen.....	1.52	1.72	Ash.....	4.10	4.63
Sulphur.....	.86	.97			
Ash.....	4.10	4.63			
				100.00	100.00
	100.00	100.00			

	As received	Moisture free
Heating value.....	{Calories 6,553 B. t. u. 11,795	{7,394 13,310
Fusion of ash.....	{Incipient 1,403° C. or 2,557° F. Complete 1,443° C. or 2,629° F.	

At the mine of P. V. Gorsuch on the John Bancroft farm in Section 8, Elk Township, a sample of Quakertown coal was cut for testing. It was taken in June, 1925, at the entry head about 200 feet from the surface where the coal was bright and solid:²

<i>Ultimate analysis</i>			<i>Proximate analysis</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	67.34	75.77	Moisture.....	11.12	....
Hydrogen.....	5.75	5.09	Volatile matter.....	36.90	41.52
Oxygen.....	19.25	10.52	Fixed carbon.....	46.42	52.22
Nitrogen.....	1.52	1.71	Ash.....	5.56	6.26
Sulphur.....	.58	.65			
Ash.....	5.56	6.26		100.00	100.00
	100.00	100.00			

	As received	Moisture free
Heating value.....	{Calories 6,623 B. t. u. 11,921	{7,452 13,413

¹Sample cut by W. Stout, P. R. Maxey, and T. R. Meyers and analytical work done by Prof. D. J. Demorest, Ohio State University.

²Sample cut by W. Stout, P. R. Maxey, and T. R. Meyers and chemical work done by Prof. D. J. Demorest, Ohio State University.

Fusion of ash { Incipient 1,457° C. or 2,654° F.
 { Complete 1,498° C. or 2,728° F.

The analyses given below are taken from various sources:

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Moisture	3.90	7.50	5.40	4.60	4.90	6.66
Volatile matter	35.90	32.20	28.20	29.00	30.70	34.40
Fixed carbon	57.15	58.70	60.20	55.80	57.80	54.00
Ash	3.05	1.60	6.20	10.60	6.60	4.94
	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	2.00	.63	.66	1.30	.65	1.28
Heating value, B. t. u.						13,431

No. 1. Stokeley farm, Section 5, Jackson Township.¹

Nos. 2 and 3. Bancroft farm, Section 8, Elk Township.²

No. 4. Lower bench, Vinton Furnace shaft, Section 31, Madison Township.³

No. 5. Upper bench, Vinton Furnace shaft, Section 31, Madison Township.⁴

No. 6. Elko mine, analysis by Francis J. Peck & Co., Cleveland, Ohio, furnished by Jerry Morrow, Wellston, Ohio.

The Quakertown coal, although it may be thin, has several features which aid considerably in its mining. The stratum is, with few exceptions, clean, that is, it is seldom divided by partings of clay or shale and rarely contains concretions or lenses of pyrite. The roof material is usually a tough shale, which is safe for the workmen and which affords a high yield of fuel. In a few localities the shale is replaced by a massive sandstone, also safe for mining. The floor is a hard, siliceous clay only a few feet thick which gives good footing for posts and pillars and which does not work up readily into plastic mud along haulways. As the coal is brittle and pure, it can be bored and shot easily. The proportion of fine to lump, however, is above the average of other beds. The high quality of the coal, the freedom from partings, and the character of the roof and floor enable the Quakertown bed to be mined at a low cost, even where the stratum is thin.

At present the only shipping mine of Quakertown coal in Vinton County is that of the Elk Fork Coal Company at Elk Fork. This mine is operated in a systematic way and is electrically equipped. Storage battery motors are used for haulage. The mine has a capacity of 250 tons per day and is located on the Hocking Valley Railway. A small wagon mine is operated on the John Bancroft farm in Section 8, Elk Township. The daily output is about 10 tons of fuel which is used locally by farmers and residents of McArthur. Neighborhood

¹Geol. Survey Ohio, Report of Progress 1870, p. 99.

²Geol. Survey Ohio, Report of Progress 1870, p. 106.

³Geol. Survey Ohio, Report of Progress 1870, p. 115.

⁴Idem.

needs of coal in northern Jackson Township are also supplied from mines on the William Walton farm near Chestnut Grove Church in Section 5. Several mines employing from one to five men were also in operation in Harrison Township in 1924. Those worked were on the farms of L. C. Boch in Section 26, of Eli Clark in Section 24, of William Scott in Section 24, and of C. C. Dozer in Section 25. Coal from these mines is hauled to Allensville, Byer, Ray, Ratcliffburg, Richmondale, Vigo, Londonderry, and Chillicothe.

CONNOQUENESSING OR MASSILLON SANDSTONE

Stratigraphy and extent

The Connoquenessing or Massillon is one of the most persistent sandstones in the Pottsville formation of Ohio, being present with a degree of continuity from Mahoning County on the north to Scioto County on the south. The name Connoquenessing comes from Pennsylvania where the sandstone is well developed along Connoquenessing Creek and tributary streams in Beaver and Lawrence counties. These deposits were described by J. P. Lesley in 1880 and more completely by I. C. White in 1881. In the report of the Ohio Survey under J. S. Newberry in 1874 it is called Massillon sandstone from deposits near that place in Stark County.

The position of the Connoquenessing sandstone is normally just above the Quakertown coal. Locally, however, through expansion and irregular deposition, it may extend downward to the Sciotoville clay and upward to the Lower Mercer coal. Invariably where well developed, it replaces other Pottsville members and rests disconformably on older beds. The thickness of the deposits varies from 10 feet or less to 60 feet or more.

The Connoquenessing or Massillon is a coarse-grained sandstone, the basal portion of which is frequently conglomeratic. The normal color is light gray to light buff but, where weathered, the shades may vary to pinks and browns. The rock is usually highly cross-bedded, which feature is especially prominent on weathered surfaces. It appears to have been laid down as a shore deposit in Pottsville seas.

In Vinton County the Massillon sandstone is above drainage in eastern Eagle, Jackson, western Swan, eastern Harrison, Richland, and northwestern Elk townships, and is well developed in large areas. It lies near the base of the Pottsville formation and frequently replaces the Bear Run and Quakertown coals and even the Sciotoville clay. Where well developed the bed is from 20 to as much as 60 feet thick.

Along the high ridges in eastern Eagle Township the Massillon

sandstone is steady and well developed. The following record taken in east central Section 36 is representative:

	Ft.	In.
Pottsville formation		
Sandstone, soft, micaceous, <i>Massillon</i>	43	0
Clay shales, light.....	5	0
Sandstone, argillaceous, and shale, siliceous.....	12	0
Logan formation		
Sandstone and shale, <i>Vinton</i>	30	0

In this locality the Massillon sandstone is coarse in texture and yellow to brown in color. It is cross-bedded, especially on weathered surfaces. The elevation of the base of the deposit is 960 feet. The member is especially prominent also along the ridges in western Jackson Township where it makes up most of the interval from the Vinton shales to the Lower Mercer coal. In Swan Township the Massillon sandstone is more local but is conspicuous near Creola, where it varies in thickness from 20 to as much as 50 feet. Similar conditions are found along Elk Fork in northwestern Elk Township. The bed is massive and persistent in all of western Richland Township. The following record, taken along the road in the northeastern part of Section 30, is approximately representative:

	Ft.	In.
Shale, yellowish gray.....	29	0
Coal blossom, <i>Lower Mercer</i>	2	0
Clay, impure.....	2	0
Shale and shaly sandstone, gray.....	16	0
Sandstone, soft, massive, <i>Massillon</i>	46	0
Covered.....	31	0
Shale, dark.....	1	0
Shale, bony, <i>Anthony</i>		2
Clay, plastic, siliceous, <i>Scioto</i>	2	6

The thickness of the bed in this part of the township varies from 20 to 60 feet and in most of the area it replaces both the Bear Run and Quakertown coals. This member is also fairly steady along the ridges in eastern Harrison Township.

Economic value

The Massillon sandstone in Vinton County is not sufficiently weather resistant for building stone as most of it on exposure crumbles rapidly to sand. It is too impure for glass sand as the bonding matter is rather large and consists of iron oxides and clay. Mica in abundance is also present. Its most likely use is for molding sand for iron and steel castings. The grain is medium and fairly uniform in size and the texture is coarsest in the lower part of the deposits. The quantity is large but the bed is not favorably located for shipment.

BEAR RUN COAL

Stratigraphy and extent

The next member in the ascending scale worthy of attention is the Bear Run coal which was named from deposits on Bear Run in northwestern Bloom Township, Scioto County. Although lacking in continuity the bed is recognized at many places in southern Ohio. It varies in thickness from a few inches to more than 2 feet and in character from pure to shaly coal. It is overlain in some localities by a black, carbonaceous shale and in other places by nodular or black band ore. These strata frequently bear brackish water fossils.

In Vinton County the Bear Run coal is due above drainage in small areas in Eagle, Harrison, Swan, and Elk townships, and in large areas in Jackson and Richland. The member, however, is very unsteady and in general is poorly developed. It is best represented in central Elk, northern Jackson, and eastern Harrison townships. Normally its position is about 12 feet above the Quakertown coal and 86 feet below the Lower Mercer limestone but these intervals vary considerably from place to place. As the Bear Run coal has little economic value, the member will be treated only in a general way.

Along the ridges in the southeastern part of Harrison Township the Bear Run horizon is marked more by a thick deposit of black shale than by coal. This condition is shown in the following record taken at the road forks in north central Section 26:

	Ft.	In.
Forks of road, elevation 950 feet.		
Shale, gray.....	6	0
Shale, dark, siliceous.....	5	0
Shale, black, fissile.....	6	0
} <i>Bear Run</i> horizon		
Shale, gray, parts covered.....	15	0
Shale, soft.....	1	0
Coal, weathered, <i>Quakertown</i>	2	0

Such deposits are also conspicuous in southern Section 24 and in northern Section 25. In western Richland Township the Bear Run coal and also the associated carbonaceous shale are replaced by a thick sandstone. The same is true in southeastern Eagle and southwestern Jackson townships. Along the ridges in the northwestern part of Jackson Township, either a thin bed of coal or a stratum of black shale marks the horizon. Near the Chestnut Grove Church in Section 5, the Bear Run coal is about 1 foot thick and lies from 6 to 10 feet above the Quakertown member. In the bed of Middle Fork in northern Section 14, the following rocks were measured:

	Ft.	In.
Sandstone.		
Shale, black, part bony, with fossils near center.....	4	0
Coal, <i>Bear Run</i>		2
Clay, impure.....	1	0

In Swan Township black shales with a few inches of coal below are locally present along Brushy Fork in sections 10 and 15. The member is also found near drainage level along Elk Fork in sections 8, 5, and 6. The following beds were exposed near the level of the stream in the western part of Section 6:

	Ft.	In.
Sandstone, shaly.....	10	0
Ore and bone shale, sparingly fossiliferous.....		2
Coal, <i>Bear Run</i>		2
Clay, impure.....	1	0

The ore is of the blackband variety and is sparingly fossiliferous. The *Bear Run* coal is best developed along Elk Fork in central Section 8 where on the Bancroft farm the member has the following thickness and relations:

	Ft.	In.
Shale, gray.....	12	8
Coal, <i>Bear Run</i>	1	4
Clay, impure.....		6
Shale, gray, siliceous.....	12	0
Coal, good, <i>Quakertown</i>	3	0
Clay, siliceous.....	1	0

In this locality the *Bear Run* coal varies from 10 inches to 1 foot 6 inches in thickness. Its normal position is about 16 feet above the *Quakertown* coal and 87 feet below the Lower Mercer limestone. This coal is somewhat shaly in character. The member is also found in a few places along Little Raccoon Creek in southeastern Richland Township where it expands in a few places to 1 foot 6 inches and where it lies about 90 feet below the Lower Mercer limestone.

Economic value

The deposits of *Bear Run* coal in Vinton County are too small and the bed too thin to be of value for more than local supplies of fuel where the thicker beds are absent. So far it has been mined at only a few places and there by stripping where the cover is shallow. In composition it varies from a rather pure coal to a bony, carbonaceous shale. Locally thin lenses of cannel coal and blackband ore are present on the horizon. The *Bear Run* is a free-burning, high volatile coal, much resembling the *Quakertown* except that it is more impure. In the

best developed deposits the bed varies in thickness from 1 foot to 1 foot 8 inches. Such deposits are of value only for small supplies of domestic fuel.

The clay associated with the Bear Run coal is everywhere thin, varying from 6 inches to 4 feet but averaging not more than 2 feet. It is generally quite siliceous in character and is more or less contaminated with ferruginous impurities. It has no qualities to recommend its use for ceramic products.

LINCOLN ORE

The Lincoln ore, mined to a small extent near Scioto Furnace during the days of the charcoal iron industry, is, in a general way, correlative with the Sand Block ore of Jackson County and with thin, isolated deposits in Vinton County. Such strata are found above the Bear Run coal and represent more an iron ore horizon than a definite bed. The beds vary in position, thickness, and composition. In Vinton County such deposits are poorly developed and have no economic value.

VANDUSEN COAL

The Vandusen coal, which was named for thin deposits in southern Jackson County, is poorly represented in the area under consideration. Its position is about midway in the interval between the Quakertown coal and the Lower Mercer limestone, which are the best benches for reference. More specifically, it lies between the Bear Run and the Lower Mercer or No. 3 coals, both uncertain in extent and character. The Vandusen coal is occasionally overlain by ore, limestone, or shale-bearing marine fossils. This member is poorly represented in Vinton County, being marked and there only locally by a few inches of carbonaceous shale.

LOWELLVILLE LIMESTONE

The Lowellville or Poverty Run limestone is the oldest of the known marine limestones of the Pottsville formation in Ohio. It is well developed near Lowellville, Mahoning County, in Washington Township, Coshocton County, and in Madison and Hopewell townships, Muskingum County. Normally the member may be represented by limestone, calcareous shale, or iron ore, all bearing marine fossils in abundance. In Vinton County no deposits of this character were recognized on the horizon.

LOWER MERCER CLAY

Stratigraphy and extent

In an interval averaging about 25 feet in thickness and lying below the Lower Mercer limestone, three coal beds with associated clays are distinctly defined throughout the Pottsville formation of Ohio. They are not all present in every locality, one, two, or even all three may be absent through replacement by sandstone or through lack of deposition. Both the coals and the clays vary considerably in thickness and in character. A bed prominent in a certain area may be thin or absent in another not far distant. The intervals of separation also change from place to place. In the early reports of the Ohio Survey no distinction was made between these three coal strata. Any one, if it became prominent, was considered Lower Mercer or No. 3 coal. The lower bed, however, is the most constant in extent and thickness and is the one that has been mined in a small way at many places in southern Ohio. On this account the name Lower Mercer or No. 3 coal is retained for the oldest stratum. The middle bed is well developed in a small area on Flint Ridge in Muskingum and Licking counties and hence is called Flint Ridge coal. The upper one lying just beneath the Lower Mercer limestone has been named Middle Mercer coal by members of the Pennsylvania Survey and is known accordingly by that name in Ohio. The associated clays are designated the same as the coals, namely, Lower Mercer, Flint Ridge, and Middle Mercer.

In Vinton County the Lower Mercer clay is present above drainage in Brown, Swan, Jackson, Elk, Richland, and Clinton townships, but in some of these the areas are small. Further, the bed is not persistent, locally being replaced by sandstone. The normal position of the member is directly below the Lower Mercer coal and about 30 feet below the Lower Mercer limestone, which is the most trustworthy bench for reference. The thickness of the clay varies from 1 to 6 feet but averages approximately 3 feet. It is generally poor in quality, being siliceous and in many places ferruginous in character. The Lower Mercer clay is treated briefly, as it has little value in Vinton County.

The Lower Mercer clay is above drainage along Raccoon Creek and Twomile Run in northwestern Brown Township, but it is everywhere thin and locally absent through replacement by sandstone. Although widely distributed in Swan Township, the member is not conspicuous, at few places being as much as 3 feet thick. Its position is from 20 to 30 feet below the Lower Mercer ore. The quality of the material is poor. Deposits similar in character are locally present throughout Jackson and Richland townships. The following record, taken near the forks of the road in northeastern Section 21, Richland

Township, shows the general stratigraphic features of the member in the western part of the county:

	Ft.	In.
Limestone, blue, fossiliferous, <i>Lower Mercer</i> , elevation 930 feet		4
Clay, clay shale, and covered.....	16	0
Coal blossom, <i>Flint Ridge</i>		3
Clay, light.....	1	0
Shale and covered.....	6	0
Coal blossom, <i>Lower Mercer</i>	2	0
Clay, siliceous, plastic, <i>Lower Mercer</i>	3	0
Sandstone, hard, massive.....	5	0

In Clinton Township this clay member is present above drainage only along Little Raccoon Creek and along McConnel Run in the western part. The deposits are not attractive for ceramic work. The Lower Mercer clay is found at the surface in all of Elk Township except the southeastern part but the bed is uncertain in extent and variable in thickness and character. Its relation to other members is shown in the following measurements taken along the road in southeastern Section 31:

	Ft.	In.
Shale, fossiliferous, <i>Lower Mercer</i>	1	0
Shale, gray.....	1	0
Coal blossom, <i>Middle Mercer</i>		6
Clay, plastic.....	4	0
Sandstone, shaly.....	2	0
Shale, gray, siliceous.....	3	4
Coal blossom, <i>Flint Ridge</i>		8
Clay, impure.....	2	0
Sandstone, soft.....	17	2
Coal, smut, <i>Lower Mercer</i> , elevation 800 feet.....		2
Clay, plastic, light, siliceous, <i>Lower Mercer</i>	3	8
Sandstone, light, clay-bonded.....	6	0

The position of the Lower Mercer clay in Elk Township is 15 to 35 feet below the Lower Mercer limestone. Usually it lies closer to the Flint Ridge clay than shown in the above section.

Economic value

The Lower Mercer clay in Vinton County is of small value as the bed is lacking in continuity and thickness and as the material is poor in quality. It is everywhere a plastic clay with a rather high content of free silica. Locally it is contaminated with ferruginous matter in the form of iron oxides and pyrite. The best developed deposits measure from 4 to 6 feet in thickness but the average is not more than 3 feet. With few exceptions, the overlying coal is too thin to be attractive for mining both coal and clay from the same entry. Further, where

the coal is thickest the clay is generally thin and impure. The Lower Mercer clay in Vinton County is not recommended as the basis for ceramic operations.

LOWER MERCER OR No. 3 COAL

Stratigraphy and extent

The Lower Mercer or No. 3 coal is present with a degree of constancy across the State from Mahoning County on the north to Scioto County on the south. Within this wide field, however, the bed is unimportant as a fuel supply, nowhere expanding so that it is mined in a large way. It is best developed in Mahoning, Vinton, Jackson, Scioto, and Lawrence counties where in small areas it measures from 1 foot 6 inches to 4 feet in thickness.

In Vinton County the Lower Mercer coal is locally present above drainage in western Brown, Swan, Jackson, Elk, Richland, and western Clinton townships. In general the member is poorly developed and in many areas it is wanting. At a few places, however, in Richland Township it expands so that it is mined for a part of the neighborhood fuel supply. The position of the Lower Mercer coal is 15 to 40 feet below the Lower Mercer limestone, the average interval from more than forty measurements being 28 feet. The thickness of the coal varies from 1 inch to 4 feet but averages not more than 1 foot 6 inches. It is usually a bituminous coal but in small areas a part or all of the bed changes to impure cannel. In some localities the horizon is marked only by black, carbonaceous shale.

Brown Township.—In Brown Township the Lower Mercer coal is due near drainage level along Raccoon Creek in sections 36, 35, 34, 33, and 32, and along Twomile Run in Section 29, but the bed appears to be largely replaced by sandstone. No coal of value was observed.

Swan Township.—Owing to the dip of the rocks, Lower Mercer coal is present about midway up the slope of the hills in western Swan Township and near drainage level in the eastern part. The bed is not persistent, being wanting in many localities. It is best developed in northern Section 7 where at a few places it has been mined by striping along the outcrop. Its stratigraphic position is shown by the following record taken on the Rebecca Clarke property:

	Ft.	In.
Shale, siliceous.....	9	0
Ore, block, <i>Upper Mercer</i>		6
Covered.....	46	6
Clay shale, dark.....	4	0
Coal, with irregular sandstone parting } <i>Flint Ridge</i>		4
Coal, hard, bony.....		8

	Ft.	In.
Shale and shaly sandstone.....	16	0
Sandstone, shaly.....	1	0
Shale, blue.....	3	0
Coal, bituminous, reported thickness.....	2	4
Coal, cannel.....		2
Clay, shaly.....	1	0
Shale, blue.....	5	0

In this locality the deposits with fair thickness are small and have little value except for local supplies of fuel. In general, the bed is only a few inches thick.

Jackson Township.—In its extension westward from Swan into Jackson Township, Lower Mercer coal is also widely distributed but poorly developed. The variation in thickness is from a soot streak to 1 foot and in composition from a rather pure coal to bone shale. Its position in respect to the Lower Mercer limestone is shown in the following measurements taken in the southwestern part of Section 29:

	Ft.	In.
Lime, blue, hard, <i>Lower Mercer</i> , elevation 980 feet.....		10
Clay and covered.....	14	8
Coal blossom, <i>Flint Ridge</i>		8
Clay and covered.....	9	0
Ore, <i>Boggs</i>		5
Shale, siliceous.....	2	0
Coal, weathered, <i>Lower Mercer</i>		6

Harrison Township.—The Lower Mercer member is found only along the high ridges in southeastern Harrison Township in sections 24, 25, and 36. The deposits are thin and for the most part shaly.

Richland Township.—In small areas in western Richland Township, the Lower Mercer coal thickens so that it is mined for a part of the local fuel supply. In the eastern part the bed is thin and in many places wanting. In southern Section 8, the Lower Mercer coal is present at an elevation of 920 feet and has a thickness of about 1 foot 6 inches. On the Simon Dixon farm in a small mine in north central Section 7, the following measurements were secured:

	Ft.	In.
Shale, siliceous.....	2	0
Coal.....		1½
Shale, coaly.....		2
Coal.....		8
Shale, dark.....		1½
Coal.....		11
Shale, coaly.....		2
Clay, very siliceous.....	3	0

In northeastern Section 16, the bed has been worked in a small way for many years on the property of Joseph Carpenter. Measurements obtained in a mine are given below:

	Ft.	In.
Sandstone, massive.....	5	0
Shale.....		6
Coal.....	} <i>Lower Mercer, elevation 880 feet</i>	7½
Clay shale.....		2
Coal.....		5½
Clay.....	1	0

The coal is of good quality and is reported to thicken to 2 feet 6 inches. Its position here is about 50 feet above the Logan formation, the interval being made up largely of Massillon sandstone. Just east of the crossroads in west central Section 30 on land of Pearl Pletcher, the member has been mined for local fuel. The elevation of the stratum is 915 feet and its thickness is reported to be 2 feet 8 inches to 3 feet 6 inches. The bed is broken by thin shale and clay partings. The most extensive mining on the horizon has been done along the ridge in the southwestern corner of Section 30, where this coal has its best thickness and purity in Vinton County. Measurements given below were secured in a mine on the Barbee property:

	Ft.	In.
Shale, black, poor roof.....	2	0
Coal, good.....	1	5
Coal, bony.....	} <i>Lower Mercer, elevation 940 feet</i>	2
Clay shale.....		3
Coal, fair.....		11

The upper bench of coal is of exceptionally good quality but the lower one is less pure. The thickness of the deposits varies from 3 feet to 4 feet 6 inches and its position is 80 feet above the Quakertown coal. Along the road in northeastern Section 30, about 2 feet of weathered Lower Mercer coal was exposed at an elevation of 900 feet. In the head of the hollow in the central part of Section 28, a small mine is also operated for local use. The record obtained on the William Nichols property follows:

	Ft.	In.
Shale, gray.....	8	0
Shale, very fossiliferous, <i>Putnam Hill</i>	2	3
Coal, exposed, <i>Brookville</i>	2	0
Clay, siliceous.....	1	0
Sandstone, soft.....	5	0
Covered, mainly sandstone.....	81	0
Sandstone, massive.....	4	0
Coal, and black shale, weathered, <i>Middle Mercer</i> coal horizon.	2	0
Clay.....	1	0
Covered.....	27	0

	Ft.	In.
Sandstone, soft.....	5	0
Coal, hard.....	} <i>Lower Mercer</i>	6½
Clay shale.....		2
Coal.....		2
		1

In the eastern part of the township, the Lower Mercer coal is thin and in many places represented only by black shale. No coal deposits of value were observed.

Clinton Township.—The Lower Mercer coal is of little interest in Clinton Township as the bed is everywhere thin and impure. The areas in which the member is present above drainage are small and are confined to the valleys of Little Raccoon Creek and its tributaries in the western part.

Elk Township.—The only exposures of Lower Mercer coal in Elk Township are along Elk Fork, Puncheon Fork, and tributaries of Little Raccoon Creek in the western part. As elsewhere, the bed is inconstant in extent, thickness, and character. Its position is from 20 to 35 feet below the Lower Mercer limestone or its representative, the Lower Mercer ore.

Along Elk Fork the member is locally replaced by sandstone but where present it is marked more by carbonaceous shale than by coal. Similar conditions are found on Puncheon Fork west of McArthur. The general stratigraphy and condition of the bed in the southwestern part of the township are shown by the following composite record taken along the road in southeastern Section 31:

	Ft.	In.
Shale, fossiliferous, <i>Lower Mercer</i>	1	0
Shale, gray.....	1	0
Coal blossom, <i>Middle Mercer</i>		6
Clay, plastic.....	4	0
Sandstone, shaly.....	2	0
Shale, gray, siliceous.....	3	4
Coal blossom, <i>Flint Ridge</i>		8
Clay, impure.....	2	0
Sandstone, soft.....	17	2
Coal, <i>Lower Mercer</i> , elevation 800 feet.....		9
Clay with coal bands.....		2
Clay, light, plastic.....	1	6

In central Section 30, the Lower Mercer coal thickens locally but is so divided by shale partings that mining is not feasible. Measurements in a small prospect on land of Edward Allender are given below:

	Ft.	In.
Shale, gray.....	5	0
Coal, good.....	} <i>Lower Mercer</i> , altitude 800 feet	10½
Shale, dark, carbona- ceous.....		
		1 10

		Ft.	In.
Coal, hard, bony, semi-cannel.....	} Lower Mercer, altitude 800 feet		9
Shale, dark, carbonaceous.....		1	6
Coal, good.....		1	2

The deposit appears to be very local. Its position is about 35 feet below the Lower Mercer limestone.

Economic value

The Lower Mercer coal in Vinton County is not important as a source of fuel as it is generally thin and impure except in a small field in western Richland Township where it is regularly mined by drifting. In a few places elsewhere small quantities of coal are obtained by stripping along stream beds. In the best deposits the Lower Mercer is a high volatile fuel with a rather low ash content. Locally, however, it varies toward the cannel variety or changes to it.

BOGGS ORE AND LIMESTONE

Stratigraphy and extent

The Boggs member was named by Orton in 1884 from ore deposits which were well developed and mined extensively on the Boggs farm near South Webster in Scioto County. This horizon is intermittently marked by ore deposits elsewhere in southern Ohio and by ore, limestone, or flint in central Ohio. The ore was worked at many places for iron smelting in the old charcoal furnaces. It was known in eastern Scioto and western Lawrence counties as the "flags" ore, in southern Hocking County as the "Union Furnace" ore, and in southwestern Perry County as the "Junction City" ore. Northward from there through Licking, Muskingum, Coshocton, and Tuscarawas counties the member is in more places represented by limestone or flint than by ore. The limestone and flint and locally the ore and associated shales bear an abundant fauna of marine origin. Normally the position of the member is about 25 feet below the Lower Mercer limestone and 3 feet above the Lower Mercer coal.

The Boggs member in Vinton County, as elsewhere in southern Ohio, is characterized by its lack of continuity, by its variability in thickness, and by its change in composition. It was formed in basins in which only locally were the conditions favorable for the precipitation of ferruginous sediments as rather pure deposits of siderite, as bonding material of sands, and as a component of blackband. In general, the matter was so dissipated through the body of the sedi-

ments that it is unnoticed. In the area under consideration the Boggs member is only occasionally present as a well-defined ore stratum. Neither limestone nor flint was observed on this horizon at any place within the county. The bed varies in thickness from 1 inch to 2 feet but in the thicker deposits it is very impure, more a ferruginous sandstone than an iron ore. The Boggs member is generally low in iron and on this account was not extensively used in the old charcoal furnaces.

Brown Township.—Iron ore representing the Boggs member is locally present in Brown Township along Raccoon Creek in sections 36, 35, 34, 33, and 32, and along Twomile Run in Section 29. The deposits are generally thin and are in many places divided into two or even three layers. Along the outcrop the ore is a limonite but under cover it is a siderite. The stratigraphy of the member is well shown by the record given below and taken along the stream in west central Section 35:

	Ft.	In.
Limestone, shaly, very fossiliferous, <i>Lower Mercer</i>	3	2
Coal smut, <i>Middle Mercer</i>		2
Clay, siliceous.....	2	0
Shale, gray.....	7	0
Coal, shaly, <i>Flint Ridge</i>		4
Shale, gray.....	7	6
Ore, kidney.....	} <i>Boggs</i> , altitude 795 feet	2
Ore, very siliceous.....		4

In the ditch at the east end of the bridge that crosses Raccoon Creek near the mouth of Twomile Run, fossiliferous shale is present on the Boggs horizon. No good section was obtained here as the overlying rocks were all covered. Along the road a short distance east of this, the following beds were measured:

	Ft.	In.
Limestone, blue, blocky, fossiliferous..	} <i>Lower Mercer</i>	1
Shale, limy, very fossiliferous.....		10
Shale, fossiliferous.....		8
Coal smut, <i>Middle Mercer</i>		4
Clay, light, siliceous.....	1	2
Sandstone, massive, soft.....	14	0
Covered.....	4	0
Ore, <i>Boggs</i> , elevation 753 feet.....		2
Shale and covered.....	8	0

The Boggs member was also exposed in the south bank of Twomile Run in central Section 29. The ore is only a few inches thick and poor in quality. This stratum is present in the bed of Raccoon Creek just above the bridge in southern Section 34, where it is an impure carbonate about 3 inches thick and sparingly fossiliferous. Its position is nearly 30 feet below the Lower Mercer ore. Along the road

about one-half mile south of New Plymouth and at an elevation of 760 feet, the Boggs member is marked by 6 inches of dark shale bearing a few fossils. It is overlain by 15 feet of gray shale and underlain by 1 foot of siliceous shale.

Swan Township.—The Boggs member is widely distributed in Swan Township, being due above drainage along all the larger streams. The bed, however, is not persistent or well developed. In some areas it is wanting through lack of deposition and in others it is replaced by massive sandstone. At a few places shale-bearing marine fossils are associated with the ore or are present alone on the horizon. A general section is sufficient to show the main stratigraphic features. Along the road west of Orland in Section 2, the following beds were exposed:

	Ft.	In.
Ore, kidney.....		3
Shale.....		4
Ore, siliceous.....		2
Shale, dark, <i>Middle Mercer</i> coal horizon.....		2
Clay, light, siliceous.....	3	0
Shale, dark, chip.....	2	8
Shale, dark.....	1	4
Coal, cannel, <i>Flint Ridge</i>		5
Clay, light, siliceous.....	2	3
Shale and shaly sandstone.....	3	10
Shale, dark gray, chip.....	1	6
Ore, small kidneys, <i>Boggs</i> , elevation 825 feet.....		3
Clay, light, shaly.....		7
Shale, gray.....	6	0

Along Brushy Fork in the northern part of the area, the horizon is marked by iron ore, ferruginous sandstone, or ferruginous shale. The deposits lie 15 to 35 feet below the Lower Mercer ore. In southern Swan Township, the Boggs member is largely replaced by sandstone.

Jackson Township.—Lack of continuity and variability in thickness, character, and position are general features of the Boggs member in Jackson Township, where it is locally present along the main ridges in the eastern and central parts. The position of the ore is 25 to 30 feet below the Lower Mercer limestone and its character a siliceous siderite or limonite, depending on the state of weathering. The following measurements, taken near the forks of the road in southern Section 29, are representative of the bed and its stratigraphy:

	Ft.	In.
Limestone, shaly, fossiliferous.....	7	11
Limestone, blue, fossiliferous.....		7
Clay and covered.....	15	0
Shale, dark, siliceous.....	3	2
Shale, dark, carbonaceous.....	3	10
Sandstone and siliceous shale, gray.....	5	0
Ore, very siliceous, <i>Boggs</i> , elevation 955 feet.....		5

In this locality the position of the Boggs member is 1 to 5 feet above the Lower Mercer coal. East of this along Middle Fork and its tributaries, the bed is only locally present, in many places being replaced by sandstone. The thickness is from 2 to 6 inches.

Richland Township.—In Richland Township the Boggs member is poorly represented, its place being taken by dark, carbonaceous shale or by gray, argillaceous sandstone. Thin local lenses, however, are found along the ridges in sections 28, 32, 33, and 34, where it was mined at a few places for use at Richland Furnace. Where observed it is a siliceous limonite about 3 inches thick.

Elk Township.—The areas in which the Boggs member is above drainage in Elk Township are small and are confined to the valleys of Elk Fork and Puncheon Fork. The deposits are thin and irregular.

Clinton Township.—In Clinton Township, the Boggs ore appears at the surface only in the western part along Little Raccoon Creek. Its position with reference to other well-recognized beds is shown in the following record taken along the road in southwestern Section 19:

	Ft.	In.
Ore and blue, fossiliferous, nodular limestone, <i>Upper Mercer</i> ..		4
Shale.....	4	0
Shale with thin ore layers.....	3	0
Coal blossom, <i>Upper Mercer</i>		8
Clay, light.....	1	4
Shale, sandy.....	4	10
Ore, irregular, kidney.....		2
Sandstone, shaly.....	11	0
Shale and covered.....	8	0
Clay shale, light and pink.....	6	0
Shale and covered.....	6	6
Ore, kidney.....	1	3
Shale.....		0
Ore, kidney.....	1	10
Shale, very fossiliferous.....		6
Shale, gray.....	2	1
Limestone, fossiliferous, blue.....		10
Clay shale.....	2	0
Coal blossom, <i>Flint Ridge</i>		2
Sandstone, shaly and covered.....	14	0
Ore, irregular, kidney, <i>Boggs</i>		6
Shale and shaly sandstone.....	3	0
Sandstone.....		3
Coal, <i>Lower Mercer</i>	1	1

Economic value

The Boggs ore in Vinton County has no value at present and was little used even in the days of the charcoal furnaces. Small quantities were obtained at a few places by stripping along the outcrop. The bed

is generally thin and uncertain, in many places giving way to shale or sandstone. The measurements vary from 1 to 8 inches but average only 3 inches. The ore is siliceous in character and in places changes to a ferruginous sandstone. Under cover the material is a siderite but where weathered along the outcrop it is a soft limonite. It belongs to the foundry class of ores as it is high in phosphorus.

FLINT RIDGE CLAY

Stratigraphy and extent

The Flint Ridge clay, lying from 5 to 15 feet below the Lower Mercer limestone, extends with moderate continuity across the State from Mahoning County on the north to Scioto County on the south. Normally it is overlain by the Flint Ridge coal which is usually not more than a few inches thick. This in turn is overlain by shales above which the Middle Mercer clay is found. In some localities the intervening shale and coal are absent in which case the Flint Ridge and Middle Mercer clays coalesce. Both clays are usually siliceous but otherwise of fair quality. The Flint Ridge clay has been employed at many places in the State for ceramic purposes.

The Flint Ridge clay is moderately persistent in Vinton County and is present above drainage in western Brown, Swan, eastern Jackson, central and western Elk, eastern Richland, and western Clinton townships. The position of the member is 5 to 20 feet below the Lower Mercer limestone or its associated ore. The average interval from more than 30 measurements is nearly 15 feet. The Flint Ridge clay expands from 1 to 7 feet in thickness but averages nearly 3 feet. It is generally siliceous and in places approaches a ganister in composition. This clay was formerly used to a small extent on Potters Ridge in the manufacture of stoneware. At present it is not regularly employed at any place within the county. As the Flint Ridge clay is not especially important it will be treated only in a general way.

Brown Township.—The deposits of Flint Ridge clay above drainage in Brown Township are confined to the valley of Raccoon Creek from New Plymouth southward to Section 32 and to the valley of Twomile Run from its mouth eastward to the central part of Section 23. The thickness of the bed is generally less than 2 feet and its position about 12 feet below the Lower Mercer limestone. The clay is very siliceous.

Swan Township.—In Swan Township the Flint Ridge clay is due well above drainage throughout the entire area but in many places it is absent from the section through replacement by sandstone or through lack of deposition. Where present the bed is not attractive

for ceramic work as in few places is it more than 2 feet thick and as it is siliceous in character. The following record, taken in the central part of Section 29, shows the general position of the Flint Ridge bed with reference to other Mercer members:

	Ft.	In.
Ore, <i>Upper Mercer</i>		4
Shale and covered.....	13	6
Ore, <i>Sand Block</i>		3
Covered.....	1	9
Coal blossom, <i>Upper Mercer</i>		6
Clay, part covered.....	4	0
Shale and covered.....	11	0
Ore, very siliceous, <i>Lower Mercer</i>		3
Shale, dark.....		3
Coal blossom, <i>Middle Mercer</i>		6
Clay, siliceous.....	2	0
Sandstone, shaly.....	4	4
Ore, kidney.....		2
Shale, gray.....	1	8
Coal and bone shale, <i>Flint Ridge</i>		6
Clay, light, siliceous, <i>Flint Ridge</i>	2	0
Sandstone and covered.....	52	0

Near Hue the Flint Ridge and other Mercer clays were mined to a small extent for the stoneware potteries that formerly were operated in that vicinity.

Jackson Township.—The Flint Ridge member is only moderately persistent along the ridges in the eastern and central parts of Jackson Township. The thickness varies from 1 to 5 feet and its position from 8 to 15 feet below the Lower Mercer limestone or ore. It is siliceous but otherwise of fair purity. The overlying coal is everywhere thin and bony.

Richland Township.—Owing to the dip of the rocks, the Flint Ridge member is present near the summits of the ridges in western Richland Township and not far above the valley floors in the eastern part. In general the deposits are not well developed. The stratigraphy is shown in the following record taken at the Wyckoff Cross-roads in northeastern Section 22:

	Ft.	In.
Coal smut, <i>Brookville</i>		2
Clay, shale, and covered.....	8	0
Sandstone, massive, soft, micaceous.....	8	4
Shale, siliceous.....	1	0
Ore, sparingly fossiliferous, <i>Upper Mercer</i>		4
Clay, shale, and covered.....	5	0
Coal smut, <i>Upper Mercer</i>		3
Clay, very siliceous.....	1	7
Sandstone and sandy shale, gray.....	24	4

	Ft.	In.
Limestone, shaly, fossiliferous.....	5	6
Shale, calcareous, very fossiliferous...	2	6
Limestone, hard, fossiliferous.....		9
Clay, <i>Middle Mercer</i>	2	5
Shale, gray, argillaceous.....	6	3
Coal, rotten, <i>Flint Ridge</i>		5
Clay, plastic, siliceous, light, elevation 874 feet, <i>Flint Ridge</i> ..	4	0
Shale, dark.....	3	4
Sandstone, gray, shaly.....	3	0
Shale, dark, siliceous.....	38	0

Elk Township.—The outcrops of Flint Ridge clay in Elk Township are confined to the valleys in the western and the central parts. Locally the member is replaced by sandstone. Its position is from 7 to 17 feet below the Lower Mercer limestone. In general the bed is too thin and the clay too siliceous to be attractive for ceramic work. The stratigraphic features are well shown in the following section taken at the plant of the McArthur Brick Company near McArthur:

	Ft.	In.
Shale, very siliceous, dark gray.....	3	6
Ore, <i>Lower Mercer</i>		2
Shale, dark.....	1	3
Limestone, blue, fossiliferous.....		8
Shale, calcareous, fossiliferous.....	1	1
Clay, light, plastic.....	2	3
Clay, dark gray, siliceous.....	4	0
Shale, carbonaceous.....		4
Coal, <i>Flint Ridge</i>		3
Clay, light, siliceous, <i>Flint Ridge</i>	3	4

At this place a sample of Flint Ridge clay was taken for testing. (See page 111.) Along with shale and Middle Mercer clay it was used to a small extent by this company for the manufacture of building brick. Where observed elsewhere in Elk Township, the thickness of the Flint Ridge clay varies from 2 to 4 feet and that of the overlying coal from 1 to 8 inches.

Clinton Township.—In Clinton Township, Flint Ridge clay is found above drainage only in the western part along Little Raccoon Creek and its tributaries. The deposits are not above the average either in thickness or in quality.

Economic value

The Flint Ridge is not an important clay member in Vinton County as the bed is generally thin and as the material has only fair ceramic properties. It is a siliceous, plastic clay of the stoneware type, vitrifying at moderate temperatures to a dense, impervious body. The

Flint Ridge and other Mercer clays were used in a small way from 1845 to 1903 for stoneware by the potters who had country shops near Hue on Potters Ridge. The general properties of the material are shown by the following tests of a sample from the pit of the McArthur Brick Company at McArthur:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	1.26	K ₂ O	.166	} Al ₂ O ₃	1.00 {
Ignition loss.....	5.79	Na ₂ O	.011		
Silica, SiO ₂	64.60	CaO	.008		
Alumina, Al ₂ O ₃	18.98	MgO	.046		
Ferric oxide, Fe ₂ O ₃	3.43	FeO	.163		
Lime, CaO.....	.15	MnO	.001		
Magnesia, MgO.....	.87				
Titanic oxide, TiO ₂	1.35	RO	.395		
Phosphorus pentoxide, P ₂ O ₅	.02				
Sodium oxide, Na ₂ O.....	.21				
Potassium oxide, K ₂ O.....	3.16				
Manganous oxide, MnO.....	.02				
Sulphur, S.....	.02				
Total carbon, C.....	.38				
Inorganic carbon, C.....	.06				

Physical tests

Working properties: Very plastic, fine grained, excellent molding properties.

Tempering water.....	22.74 per cent.
Drying linear shrinkage.....	4.60 per cent.
Drying volume shrinkage.....	14.43 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 07	1.82	5.37	22.38	Medium buff
Cone 03	3.50	10.13	22.98	Medium buff
Cone 2	5.30	15.06	16.59	Dark buff
Cone 5	6.38	17.94	6.86	Dark buff
Cone 6	6.12	17.26	0.11	Bluestone gray
Cone 7	5.64	15.99	0.06	Brown gray speckled
Cone 10	4.26	12.25	0.10	Brown gray speckled
Cone 12	1.06	3.15	0.45	Brown

Overburning temperature: Cone 7 (1,270° C. or 2,318° F.).

Best apparent burning range: Cones 2 to 6 (1,170° C. to 1,250° C. or 2,138° F. to 2,282° F.).

Total linear shrinkage at cone 6: 10.72 per cent.

Deformation temperature: Cone 17 (1,470° C. or 2,678° F.).

Possibilities: Face brick, hollow block.

The Flint Ridge clay used on Potters Ridge near Hue was mined by stripping along the outcrop where the material was weathered. It gave good results as it vitrified well, had a long burning range, took a good salt glaze, and had low shrinkage.

FLINT RIDGE COAL

Stratigraphy and extent

The Flint Ridge coal was named from deposits of cannel coal on Flint Ridge in Licking County. The member has wide areal extent in Ohio but in few places thickens so that it is mined even for local needs. In Vinton County its position is from 3 to 18 feet below the Lower Mercer limestone, but the average measurement is approximately 11 feet. The bed expands from 1 inch to 1 foot 2 inches but measures on the average about 6 inches. Further, it changes in character from rather pure coal, to bony coal, and to carbonaceous shale. It has only fair continuity, locally being absent through lack of deposition or through replacement by sandstone. The Flint Ridge member in Vinton County is of interest chiefly for its stratigraphic features, as it is everywhere too thin or too impure to be of value as a source of fuel.

Brown Township.—The exposures of Flint Ridge coal in Brown Township are confined to the valleys of Raccoon Creek and its tributaries in the northwestern part where it is present at or not far above drainage. The bed is poorly developed, the thickness where observed varying from 1 to 5 inches, and the member locally being represented by coaly shale. In this region the position of the Flint Ridge coal is 5 to 10 feet below the Lower Mercer limestone.

Swan Township.—Economically the Flint Ridge member is of small value in Swan Township as the bed averages less than 6 inches in thickness and is in many places shaly in character. It is widely distributed, however, being found not far above drainage in the eastern part of the area and well up on the hills in the western part. Along the road in southwestern Section 2, the member is present at an elevation of 830 feet, where it is represented by 5 inches of cannel coal, lying 8 feet below the Lower Mercer ore. Near the valley floors in the vicinity of Mt. Pleasant from 3 to 8 inches of coal, either bituminous or cannel, is present on the horizon. The conditions are much the same near Hue in the northwestern part of the area. The general stratigraphy of the member in southwestern Swan Township is shown in the following record secured in Section 29:

	Ft.	In.
Ore, <i>Upper Mercer</i>		3
Sandstone and covered.....	29	0

	Ft.	In.
Shale.....	5	0
Ore, very siliceous, <i>Lower Mercer</i>		5
Shale, gray.....		7
Coal, impure, <i>Middle Mercer</i>		3
Clay, dark, siliceous.....	2	9
Shale, carbonaceous.....		5
Sandstone, shaly, dark.....	7	7
Shale, hard, bony.....		2
Coal, hard, bony, <i>Flint Ridge</i> , elevation 855 feet.....		5
Clay, dark, siliceous.....	1	0
Sandstone, sandy shale, and covered.....	30	0

Along Brushy Fork and its tributaries in the vicinity of Creola, the bed is generally thin and locally absent.

Jackson Township.—In its extension westward from Swan into eastern Jackson Township the Flint Ridge coal increases neither in thickness nor in continuity. It is everywhere so thin or shaly that it has not been mined even for local needs. The following record, secured near the forks of the road in northwestern Section 36, shows the main stratigraphic features and the coal at about its maximum development:

	Ft.	In.
Ore.....		4
Flint, gray, fossiliferous.....		4
Shale, gray, siliceous.....	11	6
Shale, gray.....	1	0
Coal, shaly, <i>Upper Mercer</i>		10
Clay, impure.....	2	0
Shale and covered.....	2	0
Sandstone, soft.....	4	0
Shale and covered.....	13	0
Limestone, hard, blue, fossiliferous, <i>Lower Mercer</i>		4
Shale and covered.....	11	0
Shale, gray.....	2	0
Coal, bony.....		3
Shale, coaly.....		5
Coal, hard.....		5
Clay, gray, plastic.....	2	0

Richland Township.—The Flint Ridge member is present in the eastern and central parts of Richland Township but as elsewhere the bed is thin and impure. Its position is from 5 to 18 feet below the Lower Mercer limestone and its thickness from 3 to 10 inches.

Elk Township.—Deposits of Flint Ridge coal are present at the surface in the western and the central parts of Elk Township but are so lacking in thickness and in quality that they have not been mined even for local needs. In parts of the area the Flint Ridge and Middle Mercer coals lie close together, their clays in many places being

separated only by a few inches of coal. This condition is shown in the following record taken along the road in west central Section 28:

	Ft.	In.
Coal blossom, <i>Brookville</i>	1	0
Clay, plastic	4	0
Covered	38	0
Sandstone	8	0
Shale, gray, part siliceous	13	8
Shale, soft, fossiliferous	} <i>Lower Mercer</i>	8
Shale, hard, fossiliferous		8
Coal smut, <i>Middle Mercer</i>		2
Clay, plastic	4	8
Coal, <i>Flint Ridge</i>		2
Clay, plastic	2	2
Shale, gray, part siliceous	8	8

Clinton Township.—The Flint Ridge coal presents no unusual features in either thickness, quality, or position in Clinton Township where it is present above drainage along Little Raccoon Creek and its tributaries in the western part. The best deposits are 5 to 8 inches thick and of fair quality.

Economic value

The average thickness of the Flint Ridge coal from more than forty measurements in Vinton County is only 6 inches and the maximum measurement even in small areas in few places exceeds 1 foot. The variation in the character is marked as it changes from carbonaceous shale to cannel coal and to bright bituminous coal. The bed is much too thin to warrant drift mining or even stripping except along stream beds where the coal is solid and the cover shallow. At present the member has no value.

MIDDLE MERCER CLAY

Stratigraphy and extent

The Middle Mercer clay is present over a wide area in Ohio, entering the State in Mahoning County and leaving on the Ohio River in Scioto. It is moderately persistent except in southern Ohio where the Middle Mercer clay and coal and the Lower Mercer limestone are frequently absent. The member is best developed in Hocking, Perry, Muskingum, Coshocton, and Tuscarawas counties. Throughout this large field the thickness of the bed varies from 1 to 10 feet but averages about 3 feet 6 inches. Its position is directly below the Middle Mercer coal which lies just under the Lower Mercer limestone.

In Vinton County the Middle Mercer clay is present above drainage with fair continuity in western Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. From many measurements the mean thickness of the clay is nearly 3 feet 6 inches and the minimum and maximum are 1 and 7 feet respectively. The overlying coal in few places exceeds 1 foot in thickness and measures on the average only 5 inches. The Middle Mercer is a siliceous, plastic clay of fair purity. It was formerly employed to a small extent in the manufacture of stoneware on Potters Ridge near Hue.

Brown Township.—In Brown Township the Middle Mercer clay outcrops not far above drainage along Raccoon Creek and also along the lower courses of its tributaries. The bed is generally present but varies considerably in both thickness and character. At New Plymouth it lies about on the village level. In the Hocking Valley Railway cut near by the following measurements were secured:

	Ft.	In.
Ore, <i>Lower Mercer</i>		3
Shale, dark.....	3	10
Coal, <i>Middle Mercer</i>		1
Clay, light, plastic.....	3	0
Clay, light, very siliceous.....	3	4
Shale, blue.....	6	0
Level of railroad.		

South of this where observed in sections 35, 29, 34, and 33, the stratum is generally thin and measures not more than 3 feet. On Twomile Run it passes below the stream bed in western Section 23. The overlying coal varies from a soot streak to 8 inches in thickness.

Swan Township.—The Middle Mercer clay member is present above drainage in all of Swan Township, lying near drainage level in the eastern part and well up on the hills in the western part. Its elevation is about 840 feet in Section 1, 950 feet in Section 6, 890 feet in Section 31, and 730 feet in Section 36. As elsewhere, the deposits vary considerably in thickness and character from place to place. On the whole they are not especially attractive for ceramic work. The following record secured in Section 30 is representative of the general stratigraphy:

	Ft.	In.
Ore, block, <i>Upper Mercer</i>		5
Shale and shaly sandstone.....	14	0
Covered.....	4	0
Coal and carbonaceous shale, <i>Upper Mercer</i>		8
Shale and covered.....	30	0
Shale, calcareous, fossiliferous.....	1	0
Limestone, blue, fossiliferous.....		4
Coal, weathered, <i>Middle Mercer</i>		2

	Ft.	In.
Clay, plastic, light, lower part siliceous, <i>Middle Mercer</i>	4	0
Shaly sandstone and covered.....	9	0
Coal blossom, <i>Flint Ridge</i>		6
Clay, siliceous.....	1	6
Shale and shaly sandstone, gray.....	5	0
Shale, dark.....	3	0
Shale, gray.....	9	0
Shale, black, bony, <i>Lower Mercer</i> coal horizon.....		6
Sandstone, hard, dark.....		5
Shale, gray.....	27	0
Shale, black, fissile.....	12	0
Sandstone, shaly, part covered.....	18	0
Ore, kidney.....		4
Sandstone, coarse, shaly.....		8
Ore, siliceous, sparingly fossiliferous..		8
Shale and shaly sandstone.....	5	0

} *Lincoln*

The best deposits of Middle Mercer clay in Swan Township are present in the western and the southern parts where it expands locally to 4 feet or more in thickness and where it is rather free from visible impurities. Locally it coalesces with the underlying Flint Ridge clay. Near Hue it was formerly mined to a small extent for stoneware pottery. The material used was the soft weathered clay along the outcrop.

Jackson Township.—In Jackson Township the Middle Mercer clay occurs in all the main ridges except those in the extreme western part. The best developed deposits are found below the Lower Mercer limestone on the dividing ridge between Middle Fork of Salt Creek and Pretty Run where the clay is 3 to 6 feet thick, and of fair quality. In the southeastern part of the township, the bed is generally thin and the material very siliceous, locally changing to a clay-bonded sandstone.

Richland Township.—In its extension southward from Jackson into Richland Township few changes were noted in either the thickness or the quality of the Middle Mercer clay. In parts of the area the Lower Mercer limestone is absent, in which case the member is found 2 to 8 feet below the Lower Mercer ore. The relationship of the three Mercer clays is shown in the record given below and secured along the road in central Section 22:

	Ft.	In.
Ore, <i>Upper Mercer</i>		4
Shale and covered.....	5	0
Clay and covered.....	4	0
Sandstone.....	26	0
Clay, dark.....		6
Clay, light, siliceous, } <i>Middle Mercer</i> , elevation 885 feet part covered.....	6	6
Shale, gray.....	5	10

Shale, dark, carbonaceous, <i>Flint Ridge</i>		2
Clay, impure, <i>Flint Ridge</i>	2	0
Shale, gray.....	4	0
Sandstone, shaly.....	2	0
Shale, gray.....	3	10
Ore, <i>Boggs</i>		2
Shale, gray.....	20	0
Coal, weathered, <i>Lower Mercer</i>		8
Clay, impure, <i>Lower Mercer</i>	1	0
Shale, gray.....	6	0

Elk Township.—Exposures of Middle Mercer clay in Elk Township are confined to the valleys of the larger streams in the western and central parts. The usual thickness of the clay is from 2 to 4 feet, and that of the overlying coal from 2 to 6 inches. In this area it has not been employed for ceramic products except along with shale for building brick. A section of the bed in the pit of the McArthur Brick Company is given below:

	Ft.	In.
Shale, very siliceous, dark gray.....	3	6
Ore, <i>Lower Mercer</i>		2
Shale, dark.....	1	3
Limestone, blocky, fossiliferous.....	} <i>Lower Mercer</i>	8
Shale, calcareous, very fossiliferous...		1
Clay, light, plastic.....	} <i>Middle Mercer</i>	3
Clay, dark gray, siliceous.....		0
Shale, carbonaceous.....		4
Coal, <i>Flint Ridge</i>		3
Clay, light, siliceous, <i>Flint Ridge</i>	3	4
Shale, with concretions.....	3	0

At this place a sample of Middle Mercer clay was taken for testing. (See page 118.) Where observed along the headwaters of Little Raccoon Creek in Section 30 and along McConnell Run in sections 31 and 32, the member is 3 to 5 feet thick and of fair quality. In these localities the bed lies not far above drainage at elevations of 830 to 850 feet. The overlying coal is from 3 to 7 inches thick and is usually shaly.

Clinton Township.—The only areas in Clinton Township in which Middle Mercer clay appears at the surface are along Little Raccoon Creek and along McConnell Run where it outcrops not far above the valley floors. The deposits are not above the average either in thickness or in quality.

Economic value

In Vinton County the Middle Mercer clay is too thin in most places to be attractive for large ceramic operations and the overlying coal is likewise too thin to be considered as an adjunct in mining the

clay. Where this clay coalesces with the Flint Ridge member, however, the two may be worked very satisfactorily. The Middle Mercer clay was formerly worked to a small extent on Potters Ridge near Hue for the manufacture of stoneware. It is plastic, always siliceous, and relatively free from concretionary matter and pyrite crystals. The lower part of the bed is far more siliceous than the upper part and locally gradates into a clay-bonded sandstone. More mica is also present in the basal portion. The clay weathers readily into good plastic material. The chemical and physical properties of the Middle Mercer clay are shown by the following tests of a sample taken at the plant of the McArthur Brick Company at McArthur:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	1.20	K ₂ O	.172	} Al ₂ O ₃	1.00 {
Ignition loss.....	6.18	Na ₂ O	.013		
Silica, SiO ₂	61.22	CaO	.010		
Alumina, Al ₂ O ₃	22.34	MgO	.035		
Ferric oxide, Fe ₂ O ₃	2.76	FeO	.111		
Lime, CaO.....	.23	MnO	.001		
Magnesia, MgO.....	.78				
Titanic oxide, TiO ₂	1.10	RO	.342		
Phosphorus pentoxide, P ₂ O ₅	.03				
Sodium oxide, Na ₂ O.....	.29				
Potassium oxide, K ₂ O.....	3.84				
Manganous oxide, MnO.....	.03				
Sulphur, S.....	.06				
Total carbon, C.....	.27				
Inorganic carbon, C.....	.03				

Mineralogical examination

Sand separate is small in amount and of fine grain. It consists of abundant muscovite in bright cleavage fragments, primary quartz and quartz-sericite-clay aggregates. Zircon, tourmaline, pyrite, and rutile are found in the same separate in very small amounts. The sand grains have yellow iron stain on the surface.

The clay separate contains a very large amount of sericite (hydromica) and considerable finely divided quartz. Rutile is present in fine needles.

The striking feature of this clay is the concentration of the mica (sericite) in the clay separate.

Physical tests

Working properties: Very plastic, fine-grained, smooth, molds very well.

Tempering water.....	23.32 per cent.
Drying linear shrinkage.....	5.66 per cent.
Drying volume shrinkage.....	17.95 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 010	3.64	10.51	18.16	Medium buff
Cone 03	6.46	18.16	10.57	Light brown buff
Cone 2	7.12	19.88	7.78	Medium brown buff
Cone 4	8.97	24.56	0.41	Gray buff
Cone 5½	8.03	22.21	0.23	Bluestone gray
Cone 8	4.99	14.24	0.16	Medium gray
Cone 11	0.43	1.30	0.52	Light gray
Cone 15	....	....	0.50	Light gray

Overburning temperature: Cone 8 (1,290° C. or 2,354° F.).

Best apparent burning range: About cones 3 to 5½ (1,190° C. to 1,240° C. or 2,174° F. to 2,264° F.).

Total linear shrinkage at cone 5½: 13.69 per cent.

Deformation temperature: Cone 17 (1,470° C. or 2,678° F.).

Possibilities: Face brick, stoneware doubtful.

Burns to a clear color. Shows high shrinkage. If mixed with a siliceous clay to control shrinkage it would evidently be good for stoneware and other purposes.

MIDDLE MERCER COAL

Stratigraphy and extent

The Middle Mercer is another of the thin Pottsville coals that is widely distributed in Ohio, extending with fair continuity from the Ohio-Pennsylvania line in Mahoning County to the Ohio River in Scioto County. Throughout this field the member expands in few places sufficiently to be mined even in a small way. The average thickness of the stratum is not more than 6 inches and the maximum about 3 feet. In character it varies from a bright, bituminous coal to bone coal, to cannel coal, or to carbonaceous shale. The position of the Middle Mercer coal is directly below or near the Lower Mercer limestone. Only locally does a thin stratum of shale intervene between the two beds where the limestone is present. Where the limestone is absent and the horizon marked by Lower Mercer ore, several feet of shale may separate the ore and coal. The member is of interest chiefly for its stratigraphic features.

The Middle Mercer coal is above drainage across the central part of Vinton County or in western Brown, Swan, eastern Jackson, Elk, eastern Richland, and western Clinton townships. The bed usually measures between 2 and 10 inches and in few places expands to more

than 1 foot. The average thickness from many measurements in the county is 5 inches. It has not been mined except by stripping along stream beds where the cover is shallow.

Brown Township.—In Brown Township the Middle Mercer coal is rather persistent but thin where exposed along Raccoon Creek and the lower part of Twomile Run. The elevation of the bed is about 830 feet at New Plymouth and 730 feet in Section 32. On Twomile Run it passes below drainage in central Section 23. The usual thickness of the bed is between 4 and 8 inches and its position directly below the Lower Mercer limestone.

Swan Township.—The member is widely distributed in Swan Township, being present above drainage in the entire area. The bed, however, is poorly developed, for in many places it is represented only by a soot streak. In most of the township the normal roof, the Lower Mercer limestone, is absent, its place being taken by shale bearing the Lower Mercer ore.

Jackson Township.—The Middle Mercer coal in Jackson Township is best developed along the main ridge between Pretty Run and Middle Fork where it expands locally from 2 to 8 inches. In the eastern part the horizon is marked more often by only a soot streak.

Richland Township.—No coal deposits of value were observed below the Lower Mercer limestone which is present in the eastern and central parts of Richland Township. Locally the Middle Mercer coal has a thickness of about 6 inches in sections 22, 23, 24, 28, and 35.

Elk Township.—The Middle Mercer coal lies above the valley floors in western and central Elk Township but is of no importance as it is everywhere thin and usually impure. Locally both the associated Lower Mercer limestone and iron ore are absent.

Clinton Township.—Conditions are similar in Clinton Township where the Middle Mercer coal is present above drainage along Little Raccoon Creek and McConnel Run. Locally the member swells to 6 or 8 inches in thickness but usually it is represented only by a few inches of carbonaceous clay.

Economic value

The Middle Mercer coal in Vinton County, although widely distributed, is of trifling value as the bed is everywhere thin and in many places impure. At most it will yield only small supplies for local needs. The best coal on the horizon is a bright, dense fuel with high volatile matter and rather low ash. It mines in blocks, the horizontal

dimensions of which are about the same as the thickness of the bed. Locally this coal assumes a cannel nature but as far as observed it changes at no place to a true cannel. The best coal is present in the thicker deposits.

LOWER MERCER LIMESTONE

Stratigraphy and extent

The Lower Mercer limestone, although thin, is a wonderfully persistent bed in western Pennsylvania and eastern Ohio and on this account it is of great service to the stratigrapher as a guide in the correlation of strata in the middle portion of the Pottsville formation. It was named in 1858 by H. D. Rogers of the Pennsylvania Survey from exposures near Mercer in Mercer County of that State. The bed enters Ohio from Pennsylvania in Mahoning County where it is well represented along the Mahoning Valley. From here the member extends southward through Portage, Stark, Summit, Wayne, Tuscarawas, Holmes, Coshocton, Muskingum, Licking, Perry, Hocking, Vinton, Jackson, Scioto, and Lawrence counties into Kentucky. In Scioto and Lawrence and locally in Vinton and Hocking counties, the horizon is more frequently marked by iron ore than by limestone. In Ohio the bed was first called Zoar limestone, being thus named by J. S. Newberry in 1878 from exposures at Zoar in Tuscarawas County. The term Blue Limestone was also commonly applied to it on account of its bluish color. The Lower Mercer limestone is of marine origin and is everywhere fossiliferous. The fauna is large and the types represented vary considerably from place to place and with the kind of material. In Ohio this limestone lies on the average about 80 feet below the top and nearly 170 feet above the base of the Pottsville formation. These intervals, however, change from place to place.

In Vinton County the Lower Mercer is by far the most constant limestone in the Pottsville formation. It is present above drainage in a wide belt extending across the central part of the area and including western Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. The member is not persistent by any means for in many localities the horizon is marked only by a thin ore bed or by a slender stratum of fossiliferous shale. Further, in some areas these are wanting, their place being taken by sandstone. The position of the Lower Mercer limestone is, on the average, about 40 feet below the Upper Mercer ore and limestone, 68 feet below the Brookville coal, 98 feet above the Quakertown coal, and 150 feet above the top of the Mississippian formation. In Vinton County the member varies greatly both in thickness and in character. It may be represented by a single bed of limestone, by limestone overlain or underlain

by calcareous, fossiliferous shale, by two benches of limestone separated by fossiliferous shale, by dark flint, or by fossiliferous shale alone. The limestone layers vary in thickness from 1 inch to 1 foot 8 inches but they usually measure between 4 and 10 inches. The lower stratum of limestone is far more persistent than the upper one. The associated fossiliferous shales expand from a few inches to as much as 10 feet. The average of more than fifty measurements within the county shows that the mean thickness of fossiliferous shale and limestone is 3 feet 2 inches and of limestone alone 7 inches.

The lower bench of the Lower Mercer limestone is dark blue and in some places almost black. It is usually siliceous in character and changes to flint in a few places. This limestone is hard, dense, and tough. The jointing is such that the stratum breaks in rectangular blocks which are fairly uniform in size. The upper bench of limestone is lighter in color and more argillaceous than the lower one. In places it is so shaly that the blocks crumble on weathering much the same as true shale. The thickness of this bed varies from 2 inches to 1 foot but the usual measurement is between 4 and 8 inches. The limestone in both benches is fossiliferous but that in the upper one generally contains greater profusion of marine life. Aside from these, soft, clay-like and hard, bony shales, both fossiliferous, may be associated with the limestone in almost any order. The fossils in these are usually different from those in the more calcareous material.

Brown Township.—The Lower Mercer limestone is due above drainage only in northwestern Brown Township or along Raccoon Creek in sections 36, 35, 34, 33, and 32 and along Twomile Run in sections 29 and 23. Locally the limestone is absent, its place being taken by an iron ore. The member has fair thickness but is more largely fossiliferous shale than hard limestone.

The Lower Mercer member outcrops at an elevation of about 840 feet in the hollow east of New Plymouth. Its position here is approximately 60 feet below the Clarion coal. In the north central part of Section 35, the deposit with an elevation of nearly 800 feet consists of 4 inches of hard limestone overlain by 6 inches of very fossiliferous shale. Along the stream in the west central part of the same section the deposits are generally shaly limestone 2 to 4 feet thick. On Twomile Run the Lower Mercer limestone is exposed at an elevation of 775 feet along the road in southwestern Section 29 and again at 780 feet at the forks of the road in the east central part of the same section. The stratum is present in the bed of the stream in western Section 23 where the following measurements were secured:

	Ft.	In.
Coal and black shale, weathered, <i>Clarion</i>	5	0
Clay, light, plastic.	7	0

	Ft.	In.
Covered.....	33	0
Shale, bluish-gray.....	7	0
Shale, blue.....	8	0
Limestone, gray, blocky, fossiliferous.....	1	0
Shale, calcareous, fossiliferous.....	Lower Mercer, elevation 765 feet	
Limestone, blue, hard, blocky, fossiliferous..		
Water level.		
		10
		4

Along Raccoon Creek in sections 34, 33, and 32, the horizon appears to be marked in more places by iron ore than by limestone. Its position is not far above drainage.

Swan Township.—The Mercer group of rocks is exposed at the surface in all of Swan Township. They rise from near drainage level in the eastern part to about midway on the ridges in the western part. The Lower Mercer limestone, however, is only locally present, the horizon most commonly being marked by iron ore. Moreover, the deposits are not only thin but are more largely fossiliferous shale than hard limestone.

In the hollow in the northeast corner of Section 1, the member is present at an elevation of 840 feet and consists of 4 inches of limestone overlain by 8 inches of fossiliferous shale. Its position here is 60 feet below the Clarion coal. In the vicinity of Mt. Pleasant fossiliferous shale and iron ore are the common representatives of the Lower Mercer limestone. The following composite record taken in north central Section 4 shows this condition and its relation to other members:

	Ft.	In.
Coal blossom, <i>Clarion</i>	2	0
Clay, plastic, light to dark.....	4	0
Sandstone.....	3	0
Clay, plastic, light gray.....	3	0
Covered.....	3	0
Sandstone, soft, micaceous.....	17	6
Shale, dark gray, with thin ore layers.....	1	0
Clay, light, plastic.....	2	6
Sandstone, part shaly.....	11	0
Clay, light, plastic, <i>Brookville</i>	2	0
Covered.....	11	0
Sandstone, light, friable.....	4	0
Shale, gray, siliceous.....	10	0
Shale, dark.....	2	3
Coal, <i>Upper Mercer</i>		9
Clay, light, plastic.....	3	0
Shale, gray.....	6	0
Shale, dark, argillaceous.....	3	0
Ore, kidney.....		2

	Ft.	In.
Shale.....		2
Ore, siliceous.....		4
Clay, light, siliceous.....	2	0
Shale, gray.....	10	8
Shale, very fossiliferous.....	1	10
Ore, fossiliferous.....	} <i>Lower Mercer</i>	
		3
Clay, light gray, very fossiliferous, <i>Middle Mercer</i>	1	0
Shale, gray, siliceous.....	6	7
Covered.....	10	0
Shale, black, bony.....	1	8
Coal, <i>Flint Ridge</i>		5
Clay, shaly, dark.....	1	7
Sandstone, dark, shaly.....	1	3
Coal, <i>Lower Mercer</i>		5
Shale, bony, blocky, hard.....		7

In the northwestern part of the township only iron ore was observed on the horizon. South of this also the member is poorly developed. The only deposits found are in southeastern Section 19 and northeastern Section 30 where the limestone is 2 to 4 inches thick and the superimposed fossiliferous shale 1 to 2 feet. Its position here is nearly 48 feet below the Upper Mercer ore and its elevation approximately 920 feet. Along Raccoon Creek in southeastern Swan Township, the Lower Mercer limestone is more persistent and better developed. Locally the structure closely resembles that in parts of Jackson County. This is shown in the following measurements secured at the forks of the road in southeastern Section 26:

	Ft.	In.
Shale, siliceous, gray... }	20	0
Limestone, argillaceous,		
gray, blocky, very		
fossiliferous.....	} <i>Lower Mercer</i> , elevation 762 feet	
		7
Shale, dark gray, very		
fossiliferous.....	1	3
Limestone, blue, hard,		
blocky, fossiliferous... }		7
Shale, siliceous.....	1	5
Coal, weathered, <i>Middle Mercer</i>		2
Clay, light, siliceous.....	1	10
Shale, gray, siliceous.....	19	0

The member was observed also along the bank near the bridge across Raccoon Creek in Section 25 and along the stream in the northern part of the same area. At the latter place the structure is much the same as that given above, the upper bench of limestone being 11 inches thick, the intercalated shale 1 foot 1 inch, and the lower bench of limestone 4 inches. The elevation of the deposit is 745 feet.

Jackson Township.—The Lower Mercer limestone extends with many wants across eastern and central Jackson Township. Its ab-

sence in both large and small areas is due more largely to lack of deposition than to replacement. The member is most persistent along the main ridge between Pretty Run and Middle Fork and along that between Middle Fork and Elk Fork. The feature most conspicuous in this area is the shaly phase above the hard limestone which is similar lithologically and faunally to that so placed in many localities farther north in Hocking, Perry, Muskingum, Licking, and Coshocton counties. Further, in a few sections the limestone changes partially to a dark-colored flint not unlike that found on the Upper Mercer horizon in central Ohio.

Along the ridge road in northern Section 21, the Lower Mercer member is made up of both shaly and hard limestone. Measurements of the rocks exposed are given below:

	Ft.	In.
Ore, very siliceous, <i>Upper Mercer</i>		4
Sandstone, light, soft.....	10	4
Ore, very siliceous, <i>Sand Block</i>		8
Sandstone, shaly.....		8
Coal blossom, <i>Upper Mercer</i>		2
Clay, light, siliceous.....	2	0
Shale, sandstone, and covered.....	22	0
Clay and shale.....	5	0
Ore, <i>Lower Mercer</i>		2
Limestone, very shaly, } gray, fossiliferous....	Lower Mercer, elevation 1,010 feet	4
Limestone, blue, fossiliferous.....		
Clay and covered.....		11
	14	0

Exposures at an elevation of 1,010 feet along the road in the southwestern part of this section show much the same thickness of hard and shaly limestone as given in the above record. Deposits similar in character are present at 990 feet on the knob in the southeastern part of the area. At the sharp turn of the ridge road in southeastern Section 20, the lower stratum consists of dark limestone with large masses of black flint. The thickness of the bed is about 1 foot and its elevation nearly 1,010 feet. In the southern part of Section 29 the Lower Mercer member is especially well developed and is present in all the high knobs. Just east of the forks of the road the following measurements were secured:

	Ft.	In.
Limestone, shaly, very } fossiliferous.....	Lower Mercer, elevation 990 feet	7
Limestone, blue, hard, } fossiliferous.....		
Clay and covered.....		7
	15	0
Shale, dark, siliceous.....	3	2
Shale, dark, carbonaceous.....	3	10
Sandstone, shaly, and shale, siliceous.....	5	0
Ore, very siliceous, <i>Boggs</i>		5

On the knobs of the ridge in northwestern Section 34, the member is regularly present at an elevation of approximately 970 feet. In its extension eastward the deposits are more local and have less thickness. The following record, taken in a ravine in southeastern Section 24, is representative of the member and of its relations to other stratigraphic units:

	Ft.	In.
Shale, gray.....	15	0
Shale, dark, <i>Brookville</i> coal horizon.....		1
Clay, light, siliceous.....	4	6
Clay, dark, <i>Tionesta</i> coal horizon.....		2
Clay, light, siliceous.....	3	10
Sandstone, light, soft, shaly.....	12	0
Ore, <i>Upper Mercer</i>		4
Shale, sandstone, and covered.....	33	0
Sandstone, ferruginous.....		6
Shale, gray, siliceous.....	8	4
Coal, not well exposed.....		8
Clay, siliceous.....	2	0
Shale and covered.....	5	6
Shale, dark, very fossiliferous.....	} <i>Lower Mercer</i> , elevation 900 feet	8
Limestone, dark, very fossiliferous.....		3
Shale, dark, very fossiliferous.....		4
Shale, dark, siliceous.....		2
Coal, <i>Middle Mercer</i>		1
Clay, light.....	1	7
Coal, bony, <i>Flint Ridge</i>		6
Shale, bony.....		10
Clay.....		

The fossils in these shales are not only abundant but are well preserved, thus affording good collecting. The member extends southward with little change in character or in thickness across Section 25 into the northern part of Section 36, where its elevation is 900 to 915 feet.

Richland Township.—In this township the Lower Mercer member shows the same erratic changes in thickness and in character that it does in Jackson Township to the north. It also lacks continuity, in many places being absent. Usually only one bench of hard limestone, 4 inches to 1 foot thick, is present. Along with this, however, 1 to 8 feet of soft clay shale or shaly limestone is found in many deposits. During this invasion of the sea, deposition took place in more or less isolated basins in which a diversity of conditions prevailed, thus resulting in different kinds of strata and in different orders of arrangement.

In a general way, the Lower Mercer limestone is present in the

eastern half of Richland Township. The following record, taken along the abandoned road in central Section 1, shows its position in relation to others higher in the geological column:

	Ft.	In.
Limestone and flint, <i>Vanport</i> , loose blocks about in place . . .	2	0
Covered	13	0
Shale and coal, <i>Winters</i>	1	0
Clay, not well exposed	4	6
Flint, black, <i>Zaleski</i>		10
Covered	4	2
Coal blossom, <i>Ogan</i>	1	0
Clay and covered	10	0
Covered	17	0
Coal, <i>Brookville</i> , reported thickness	1	0
Clay and covered	4	0
Shale, siliceous	6	4
Ore, kidney	} <i>Upper Mercer</i>	4
Flint, dark gray, fossiliferous		4
Shale, very siliceous		15
Covered	26	0
Limestone, shaly, bluish-gray, fossiliferous	} <i>Lower Mercer</i> , elevation 860 feet	5
Limestone, hard, blue, fossiliferous		1
Level of Chillicothe-McArthur road.		1

In the above section the intervals from the Lower Mercer limestone to the members in the upper part of the Pottsville and the lower part of the Allegheny formations are about normal for the region. Further, the most important beds are represented. At this place the shaly phase of the Lower Mercer member, 5 feet or more thick, is almost identical lithologically with that in central Ohio, showing like conditions of deposition.

The Lower Mercer limestone is present in gullies north of the road in central Section 2 and is again exposed on several high knobs along the ridge in Section 3. In the central part of this area the shaly phase is 6 to 12 feet thick and the underlying hard limestone 5 to 10 inches. The elevation of the deposits is nearly 940 feet. Along the road in east central Section 11, the bed has the following thickness and structure:

	Ft.	In.
Coal blossom, <i>Ogan</i>		8
Clay, siliceous, plastic	2	0
Shale, gray	8	0
Shale, very fossiliferous, <i>Putnam Hill</i>	2	0
Coal, weathered, <i>Brookville</i>		6
Clay, siliceous, light	1	0
Sandstone and covered	17	0
Sandstone, soft, micaceous	16	0
Covered	10	0

	Ft.	In.
Coal blossom, <i>Bedford</i>		6
Clay, siliceous, plastic.....	1	6
Sandstone, shaly.....	11	6
Shale, dark, very siliceous.....	1	6
Coal blossom, <i>Upper Mercer</i>	1	0
Clay, shale, and covered.....	4	0
Shale, parts covered.....	8	8
Ore, blocky, <i>Lower Mercer</i>		2
Shale, gray, siliceous.....	2	4
Limestone, blue, shaly, } fossiliferous.....	4	10
Limestone, blue, hard, } fossiliferous.....		
		8

Lower Mercer, elevation 900 feet

The stratigraphic features of overlying beds in this locality are well shown in the above record as are also the main characteristics of the Lower Mercer member. Just east of the Wyckoff Crossroads along the line between sections 15 and 22, it is made up of 9 inches of hard limestone, 2 feet 6 inches of soft shale, and 5 feet 6 inches of shaly limestone, all fossiliferous. The fauna is large and the specimens are well preserved. Deposits similar in character and thickness are present in northern Section 23. Just north of the road in the southeastern corner of Section 13, the full thickness of the Lower Mercer limestone was exposed in a gully. The measurements obtained are given below:

	Ft.	In.
Ore, kidney, <i>Lower Mercer</i>		2
Shale, dark, siliceous.....		4
Limestone, shaly, very } fossiliferous.....	5	6
Limestone, blocky, ar- } gillaceous, fossilifer- } ous.....		
		5
Shale, soft, calcareous, } fossiliferous.....	1	7
Limestone, blue, hard, } blocky, fossiliferous..		
Coal, reported thickness, <i>Middle Mercer</i>	1	8
		6

Lower Mercer, elevation 840 feet

It is thus seen that in the above deposit four rather distinct kinds of material are present on the horizon. These differ not only in physical and chemical properties but also in the quantity and range of marine life. The lower stratum may be considered general across the State, the second and third layers are best represented in southern Ohio in Hocking, Vinton, and Jackson counties, and the upper bed is most prominent in central Ohio in Perry, Muskingum, Licking, and Coshocton counties. Along the road that leads from the valley to the ridge in east central Section 29, the member is present at an

elevation of 980 feet. Its position here is about 50 feet below the Upper Mercer ore and 78 feet below the Brookville coal. In a ravine on the farm of L. R. Atwood in west central Section 36, the Lower Mercer member has the following structure:

	Ft.	In.
Limestone, shaly, very fossiliferous.....	2	0
Limestone, blue, fossiliferous.....	3	8
Shale, gray.....		2
Shale, black, small fossils.....		2

Lower Mercer, elevation 830 feet

Elk Township.—In general, in Elk Township the deposits of Lower Mercer limestone are somewhat local in distribution and are rather poor in development. It exhibits somewhere, however, all the features that it has in areas farther west and north. Most of the deposits are rich in marine fauna and thus afford excellent collecting. The member is above drainage in the western half of the township.

Along the road in central Section 5, the Lower Mercer member is present at an elevation of 840 feet and consists of a few inches of hard limestone and about 1 foot of fossiliferous shale. The latter material alone marks the horizon in the southeastern corner of Section 8. In central Section 17, this member has excellent thickness and about all the different phases, as shown in the following record taken at an exposure along the stream:

	Ft.	In.
Limestone, shaly, dark gray, very fossiliferous.....	5	0
Limestone, dark gray, blocky, shaly, very fossiliferous.....	2	6
Shale, dark, soft, fossiliferous.....		8
Shale, hard, dark, bony, small fossils.....		10
Limestone, hard, blocky, blue, fossiliferous....	1	1

This locally affords excellent collecting. Other exposures with much the same thickness are also present along the stream in the eastern part of the same section. The position of the member here is 43 feet below the Upper Mercer ore, 64 feet below the Putnam Hill limestone, and 82 feet below the Winters coal. Well developed deposits are also present, at an elevation of 840 feet, in west central Section 30. South of this the member is thin and uncertain. Along the road in southeastern Section 31, the horizon is marked by only 1 foot of

marine shale and near the road forks in the western part of Section 32, by 8 inches of limestone and 1 foot of shale. At the latter place the bed is 830 feet above tide. In Rock Hollow in western Section 33, the Lower Mercer member has the following thickness and structure:

	Ft.	In.
Limestone, gray, blocky, argillaceous, fossiliferous.....		10
Shale, gray, fossiliferous.....	2	6
Shale, black, very fossiliferous.....		6
Limestone, hard, dark gray, fossiliferous....		6

Lower Mercer, altitude 780 feet

Fossiliferous shale, 1 foot 4 inches thick, marks the horizon along the road in west central Section 28. In the pit of the McArthur Brick Company in the southeastern part of the same section, the deposit has the following thickness and structure:

	Ft.	In.
Shale, gray.....	3	6
Ore, irregular.....		2
Shale, dark blue, fossiliferous.....	1	3
Limestone, gray, shaly, blocky, fossiliferous.....		8
Shale, blue, fossiliferous.....		9
Limestone, hard, blue, fossiliferous....		4

Lower Mercer

Along Elk Fork east of McArthur, the member is represented by an iron ore or by a thin shale bearing a few fossils. It is below drainage in the eastern part of the township.

Clinton Township.—The Lower Mercer limestone is present not far above the valley floors along Little Raccoon Creek and McConnel Run in western Clinton Township, but owing to thick deposits of silts along these streams it is exposed for measurement at few places. No new features were observed. Locally the member is absent, its position being indicated by a thin stratum of iron ore.

In central Section 5, thin deposits of limestone and shale are present at an elevation of approximately 800 feet. Along the road in west central Section 18, the following measurements were secured:

	Ft.	In.
Sandstone, soft, micaceous.....	10	0
Clay, siliceous, part covered.....	4	0
Shale, very siliceous.....	7	0
Coal, weathered, <i>Bedford</i>		7
Clay and covered.....	8	5
Shale, shaly sandstone, and covered.....	15	4
Coal blossom, <i>Upper Mercer</i>		6

	Ft.	In.
Clay, plastic, siliceous.....	2	0
Shale and covered.....	7	3
Ore, kidney.....	1	2
Shale, gray.....		2
Ore, kidney.....		1
Shale, gray, calcareous, } very fossiliferous.....	1	7
Limestone, gray, shaly, } blocky, very fossilifer- } ous.....	Lower Mercer, altitude 795 feet	
Shale and covered.....	2	0
Limestone, blue, blocky, } hard, fossiliferous.....		8

The member has similar thickness and character where exposed along the road in southwestern Section 19 and in the spillway at Alma Lake in Section 29.

Economic value

The Lower Mercer limestone in Vinton County is of small economic value as the lower stratum, the only layer of fair purity, averages not more than 7 inches in thickness and at few places expands to as much as 1 foot 6 inches. The deposits are thus too thin to be worked in a large way. Small quantities, however, may be obtained at low cost along stream beds where the covering has been largely removed by erosion. In the better grades of stone the content of calcium carbonate is 80 to 90 per cent and that of magnesium carbonate 1 to 3 per cent. It is sufficiently pure for the calcined product to slake readily on exposure to moisture, hence it may be burned for agricultural purposes. In parts of the county a supply of lime sufficient for farm needs may be obtained from this source as both limestone and coal are available. One cubic foot of this stone weighs 166 pounds or 12 cubic feet nearly one ton. For the fuel in calcination of limestone in stacks either coal or wood may be used. The quantity required per ton of stone is 600 to 700 pounds of coal or nearly one-half cord of wood. The dense, tough nature of the Lower Mercer limestone recommends it for use in road building and for concrete work, but the thinness of the bed excludes its being so employed except in local areas. The fossiliferous shales associated with the hard limestone are somewhat calcareous in composition. Their value, however, is chiefly in contributing some lime to the soils derived, through decomposition, from such deposits.

LOWER MERCER ORE

Stratigraphy and extent

The Lower Mercer ore, mined rather extensively in Scioto, Jack-

son, and Vinton counties for iron smelting in the charcoal furnaces, was called by the miners the "little red block," "fine kidney," and "blue limestone" ore. In the report of 1870 it is described by E. B. Andrews as the "little red block" ore. It extends from Mahoning County on the north to Scioto County on the Ohio River but it is subject to many wants. Moreover, the bed is everywhere thin, in few places expanding to more than a few inches. The member was mined most extensively in southern Ohio where it has fair continuity and good quality for a native material.

In Vinton County the Lower Mercer ore is locally present across the central part or in northwestern Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. It was mined most extensively in Richland Township where it was used for iron smelting in Cincinnati furnace. Where both the ore and the Lower Mercer limestone are present, the position of the ore is 2 to 10 feet above the limestone. The mean intervals to the overlying Sand Block and Upper Mercer ores are 23 and 34 feet respectively and to the underlying Boggs 31 feet. The member varies from 1 to 9 inches in thickness but averages about 3 inches. Usually it is represented by a single stratum but locally it may be divided into two or even three layers. Most of the deposits are sparingly fossiliferous, the fauna being of marine origin and similar to that in the underlying limestone. However, the species are fewer and the forms more impoverished.

The Lower Mercer ore is poorly represented in northwestern Brown Township. At the forks of the road in southern Section 34, the following measurements were secured:

	Ft.	In.
Ore, kidney, <i>Lower Mercer</i> , elevation 760 feet.....		3
Clay and covered.....	8	8
Coal blossom, <i>Flint Ridge</i>		1
Clay, siliceous.....	1	0
Shale, argillaceous.....	6	0
Shale and covered.....	20	0
Ore, carbonate, siliceous, sparingly fossiliferous, <i>Boggs</i>		3
Shale.....	2	0
Water level, Raccoon Creek.		

Formerly the member was mined in a small way by stripping along the outcrop in many places in Swan Township. Along the road in the southwestern part of Section 2, at an elevation of 841 feet, the deposit consists of two benches of ore, 2 and 3 inches thick, respectively, separated by 4 inches of shale. The structure and thickness of the member are much the same also in the vicinity of Mt. Pleasant in Section 4. Near the forks of the road in eastern Section 6, the following rocks were exposed:

	Ft.	In.
Ore, blocky.....		5
Ore, impure, weathered flint.....		4
} <i>Upper Mercer</i>		
Clay, siliceous.....	2	0
Shale and covered.....	12	6
Coal blossom, <i>Upper Mercer</i>		6
Clay, light, plastic.....	1	6
Sandstone, shaly, parts covered.....	10	6
Ore, kidney, in two layers, <i>Lower Mercer</i> , elevation 972 feet		8
Clay, light, plastic, <i>Middle Mercer</i>	2	0
Shale, gray, siliceous.....	7	0
Ore, kidney, stray bed.....		3
Clay, impure, plastic, <i>Flint Ridge</i>	2	0

The Lower Mercer ore is 3 inches thick near the Ebenezer School in northern Section 7. It shows little change in the central and the southern parts of the township, usually being present but everywhere thin.

The position of the member is about midway up the slopes of the hills in the eastern part of Jackson Township and near the summits of the ridges in the central part. The development is not above the average in any part of the area. Its elevation above tide is about 1,030 feet in Section 1, 1,095 feet near the Chestnut Grove Church, in Section 5, 920 feet in Section 36, and 1,015 feet in Section 32.

A part of the ore supply for Cincinnati furnace was drawn from the Lower Mercer member in Richland Township where the bed is moderately persistent over most of the area. Along the road in central Section 11, the ore is 2 inches thick and lies 2 feet 4 inches above the top of the Lower Mercer limestone which measures 5 feet 6 inches. Its relation to the Upper Mercer member is shown in the following record taken along the line in the southeastern part of Section 16:

	Ft.	In.
Coal blossom, <i>Brookville</i>	1	0
Clay, plastic, light.....	3	0
Covered.....	15	0
Shale, siliceous.....	3	0
Flint, siliceous, light gray to dark, <i>Upper Mercer</i>		4
Shale and covered.....	21	0
Clay, poorly exposed.....	2	0
Shale and shaly sandstone.....	8	0
Ore, kidney, siliceous, <i>Lower Mercer</i> , elevation 930 feet.....		3
Clay, shaly, light, <i>Middle Mercer</i>	1	6
Shale, gray.....	6	0
Coal, weathered, <i>Flint Ridge</i>		3
Clay, light, shaly.....	2	0
Shale.....	5	0

In southeastern Section 13 and northeastern Section 24, from 2 to 4 inches of ore is present just above the Lower Mercer limestone

which is well developed. Along the ridge in central Section 34, the bed was formerly mined by stripping. The thickness of the member is 2 to 6 inches. Old ore benches are also present at an elevation of 930 feet on the ridge in the central part of Section 33 and south of this in Section 4. Some deposits were also worked along Jackman Ridge in sections 34 and 3. The ore is regularly broken by joint planes into blocks which weather into concentric layers known to the miners as kidneys. Along the outcrop it is a limonite but under cover it is a hard siderite.

The Lower Mercer ore is not a prominent bed in Elk Township for in many localities it is wanting and where present the stratum is thin and impure. It is present above drainage only in the western half. The member is also lacking in continuity and is variable in thickness and quality along Little Raccoon Creek and McConnel Run in the western part of Clinton Township.

Economic value

At present the Lower Mercer ore is of interest chiefly for its stratigraphic features although formerly in the days of the charcoal furnaces it was considered one of the important iron-bearing strata of southern Ohio. It belongs to the block or kidney type of ores, depending on its thickness and state of weathering. On the outcrop the material is a soft shelly limonite but under cover it is a dense siderite. Analysis of the ore usually shows from 25 to 45 per cent iron, from .200 to .400 per cent phosphorus, and .30 to .60 per cent manganese. It belongs to the class of ores well fitted for making foundry iron. Owing to its soft and porous nature, it smelted readily in the short stacks of the charcoal furnaces. In Vinton County the Lower Mercer ore was mined largely in the vicinity of Cincinnati furnace in Richland Township and near Creola in Swan.

UPPER MERCER CLAY

Stratigraphy and extent

In Ohio the clay associated with the Upper Mercer or No. 3a coal is not an important stratum for the manufacture of ceramic products. It is best developed in a small field in eastern Scioto County where it is used at South Webster for making iron mottled building brick. In its extension northward across Jackson into Vinton County the member so decreases in thickness and in continuity that it has little value for such purposes. From more than thirty measurements in Vinton County the average thickness of the bed is 2 feet 3 inches

and the maximum measurement 5 feet. The position of the clay is about midway in the interval between the Lower Mercer and the Upper Mercer limestones or where these are absent between their kindred ores. More directly it lies only a few feet below the Sand Block ore, which member, however, is present at few places. The material is everywhere a plastic clay, siliceous in character, and dark to light gray in color. The associated coal is too thin to be considered as an adjunct in mining the clay as it averages only about 8 inches. The Upper Mercer clay is present locally in western Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. The member will be traced only in a general way.

The deposits of Upper Mercer clay along Raccoon Creek and Twomile Run in western Brown Township are local in extent, poor in quality, and their usual measurement is between 1 and 3 feet. The member is above drainage in all of Swan Township but is very erratic in distribution and in character. The general stratigraphy is well shown in the following record taken in a ravine in south central Section 29:

	Ft.	In.
Ore, blocky, <i>Upper Mercer</i>		4
Shale and covered.....	13	6
Ore, <i>Sand Block</i>		3
Shale and covered.....	1	9
Coal blossom, <i>Upper Mercer</i> or <i>No. 3a</i>		6
Clay, siliceous, plastic, part covered, <i>Upper Mercer</i>	4	0
Shale and covered.....	11	0
Ore, kidney, very siliceous, <i>Lower Mercer</i>		3

In some of the exposures the material is very siliceous, being more a clay-bonded sandstone than a true clay. Root impressions are common in these deposits. The thickness of the bed is ordinarily between 1 foot 6 inches and 3 feet.

The member is fairly persistent in the eastern part of Jackson Township but it is not above the average either in thickness or in quality. Its position with reference to the Upper Mercer ore is shown in the record given below and taken at the road forks in central Section 21:

	Ft.	In.
Ore, blocky, <i>Upper Mercer</i>		4
Shale and covered.....	1	6
Coal smut, <i>Bedford</i>		2
Clay, shale, and covered.....	6	10
Coal blossom, <i>Upper Mercer</i> or <i>No. 3a</i>		10
Clay, plastic, light, siliceous, <i>Upper Mercer</i>	3	4
Shale, gray, siliceous.....	5	0
Crossroads, elevation 1,032 feet.		

Along the ridges in eastern Richland Township the Upper Mercer clay is local in extent and poor in quality, and the deposits are not attractive for ceramic work. The following measurements, taken along the road in northeastern Section 24, show its position with reference to the Upper Mercer flint and ore and to the Lower Mercer ore and limestone:

	Ft.	In.
Ore and flint, <i>Upper Mercer</i>		4
Clay and covered.....	7	0
Shale, gray, siliceous.....	14	0
Shale, black, coaly, <i>Upper Mercer</i> coal horizon		8
Clay, light, plastic, <i>Upper Mercer</i>	1	0
Sandstone, soft, argillaceous.....	5	0
Sandstone, dark, carbonaceous.....		6
Sandstone, light, argillaceous.....	15	6
Ore, kidney, <i>Lower Mercer</i>		3
Shale, dark, calcareous.....	1	3
Limestone, shaly, <i>Lower Mercer</i> , elevation 840 feet.....	3	0

The Upper Mercer clay is widely distributed in Elk Township but as elsewhere it is lacking in development and in quality. The average thickness of the clay is about 2 feet and that of the overlying coal only 7 inches. It is best represented in the northeastern part as shown by the following measurements taken along the road in the southwestern part of Section 12:

	Ft.	In.
Shale, very fossiliferous, <i>Putnam Hill</i>	1	6
Coal, weathered, <i>Brookville</i>		8
Clay, plastic, light to dark.....	5	0
Sandstone, light, clay-bonded.....	4	0
Sandstone, yellowish, argillaceous.....	1	6
Shale, dark.....	5	8
Ore, kidney, <i>Upper Mercer</i>		2
Shale, siliceous, gray.....	12	8
Ore, dark, very siliceous, <i>Sand Block</i>		3
Shale, dark.....	1	9
Coal, <i>Upper Mercer</i>		5
Clay, plastic, siliceous, light, <i>Upper Mercer</i> , elevation 755 feet	4	11
Sandstone, shaly.....		8
Shale and shaly sandstone.....	8	4

In this locality the Upper Mercer clay is siliceous in character but otherwise of fair purity. The member shows no improvement in Clinton Township where it is locally present along Little Raccoon Creek and McConnel Run and disappears below drainage near Dundas and Hamden Furnace.

Economic value

The Upper Mercer clay in Vinton County has neither the thick-

ness nor the purity to fit it for ceramic operations. Further, the overlying coal is too thin to aid substantially in the mining of the material and in its conversion to useful products. It belongs in the low heat duty class of clays which are best fitted for the manufacture of stoneware and iron mottled building brick. This material has fair plasticity, moderate shrinkage, both drying and burning, and good body strength, but the burning range is not wide. The Upper Mercer clay is not used at any place in Vinton County.

UPPER MERCER OR No. 3a COAL

Stratigraphy and extent

In the interval between the Lower Mercer and the Upper Mercer limestones, or, in their absence, between their kindred ores, two coal horizons are somewhat distinctly defined across the State. Neither bed is persistent but each occurs with fair regularity over rather wide areas. In southern Ohio this interval ranges from 35 to 45 feet in thickness but in the central and eastern portions it measures more often between 20 and 30 feet. The lowest coal bed, lying about midway in this interval, is known as the Upper Mercer or No. 3a coal. It is best developed in eastern Scioto County where it is known locally as the Webster Block coal. The upper bed, called the Bedford coal, lies directly or closely below the Upper Mercer limestone, flint, or iron ore, whichever material may mark the horizon. This member is best represented in Coshocton and Holmes counties where it is a cannel coal with excellent thickness. Other beds of coal appear in this interval, more in the nature of local, erratic lenses but these are not sufficiently continuous or distinct to warrant correlation. The most prominent is a thin coal occurring in isolated areas only a few feet above the Lower Mercer limestone.

In Vinton County the Upper Mercer coal lies on the average 24 feet above the base of the Lower Mercer limestone, 15 feet below that of the Upper Mercer ore, and 4 feet below that of the Sand Block ore. These intervals, however, are subject to considerable variation, due to the lenticular character of many of the deposits making up this group of rocks. In this county the Upper Mercer coal is thin, averaging only 8 inches, and nowhere expanding to more than 1 foot 6 inches. In character it varies from a bright, bituminous coal, to bone coal, to cannel coal, and to coaly shale. On account of its impoverished condition, the member will be traced only in a general way.

Along Raccoon Creek and Twomile Run in western Brown Township, the Upper Mercer member is either absent or is represented only by a soot streak of coal. Many wants are also found in Swan Township. Locally, however, it is better defined, from 4 to 8 inches of fair quality

fuel being present on the horizon. The best deposits observed were in sections 2, 6, 21, 29, and 30. The member is usually present but thin along the ridges in eastern Jackson Township. The following measurements, taken along the road in west central Section 10, show the main stratigraphic features:

	Ft.	In.
Ore and flint, <i>Upper Mercer</i> , about in place.....		4
Shale and covered.....	10	0
Ore, nodular, <i>Sand Block</i>		6
Shale, gray to dark.....	6	0
Coal, shaly, <i>Upper Mercer</i> , elevation 1,050 feet.....	1	2
Clay, siliceous, plastic.....	2	0

Deposits from 6 to 10 inches thick are also present in sections 16, 21, 35, and 36, but in some of these the coal is shaly. The member has fair continuity in eastern Richland Township but nowhere thickens sufficiently for mining even in a small way. Much the same is true in Elk Township. The main stratigraphic features are shown in the record given below and taken along the road in northwestern Section 15:

	Ft.	In.
Shale, very fossiliferous, <i>Putnam Hill</i>		6
Coal, weathered, <i>Brookville</i>	1	3
Clay, plastic, good.....	6	0
Sandstone, light, clay-bonded.....	11	0
Sandstone and shale.....	22	3
Shale, dark.....		4
Coal, weathered, <i>Upper Mercer</i> , elevation 817 feet.....		9
Clay, plastic, siliceous, light.....	1	8
Shale and covered.....	21	0
Ore, kidney, <i>Lower Mercer</i>		2
Shale, siliceous.....	6	10
Coal, weathered, <i>Middle Mercer</i>		7
Clay, impure.....	1	0

In Clinton Township, the Upper Mercer coal is best developed in the vicinity of Hamden Furnace where it thickens locally to nearly 1 foot. Its position here is 10 to 15 feet below the Upper Mercer ore and 20 to 30 feet above the Lower Mercer member. Elsewhere in the western part of the township, the bed is thin or wanting.

Economic value

The Upper Mercer, like other coals in this group of rocks, is widely distributed in Ohio but only in very small fields is it sufficiently well developed to furnish fuel even for local needs. In Vinton County the supply from this source is negligible. The member has not been regularly mined by drifting at any place, but along stream beds where

erosion has removed most of the overburden small quantities of coal are secured by stripping. This fuel is high in volatile matter and hence burns freely and with a long flame. The content of sulphur is low and the ash is clay-like in character and moderate in quantity. The bed is usually free from partings of either clay or bone shale. Like most thin strata, it is regularly broken by joint planes so that it mines in rectangular blocks, hence it is often called a block coal. In general, the Upper Mercer coal is well fitted for domestic use and in the future when the thicker beds are exhausted it may be of real service for such purposes.

SAND BLOCK ORE

Stratigraphy and extent

The Sand Block ore was formerly used in a small way by some of the charcoal furnaces in Scioto, Lawrence, Jackson, and Vinton counties. It was named Sand Block ore by the miners as it was blocky in structure and as it was more siliceous in character and rougher in appearance than either the underlying Lower Mercer or Little Red Block ore or the overlying Upper Mercer or Big Red Block member. It was considered least valuable of the three block ores. The general position of the Sand Block ore is about two-thirds of the way up in the interval between the Lower Mercer and the Upper Mercer ores and only a few feet above the Upper Mercer coal.

In Vinton County the Sand Block ore is an uncertain and variable element. It changes from a well stratified ore of blocky structure to concretionary nodules dissipated throughout several feet of shale. Further, in many areas it is completely wanting. The material varies also in character from a rather rich mellow ore to one decidedly siliceous or argillaceous. During this stage the conditions in the brackish water swamps were only locally favorable for the deposition of ferruginous sediments in sufficient quantities to form definite ore bodies. Under cover the ore is a siderite but along the outcrop, where weathering has been active, it is a limonite. The thickness of the ore varies from 1 to 8 inches but the usual measurement is about 3 inches. The general position of the Sand Block ore in Vinton County is 11 feet below the Upper Mercer ore, 4 feet above the Upper Mercer coal, 23 feet above the Lower Mercer ore, and 29 feet above the base of the Lower Mercer limestone. As the deposits have no commercial value at present, the member will be treated briefly.

Formerly the Sand Block ore was mined in a small way at a number of places in Swan Township. It was worked most extensively along the ridges west of Creola. The main stratigraphic features are shown in the following measurements taken in southern Section 29:

	Fr.	In
Ore, blocky, <i>Upper Mercer</i>		4
Shale and covered.....	13	6
Ore, irregular, siliceous, <i>Sand Block</i>		3
Shale and covered.....	1	9
Coal blossom, <i>Upper Mercer</i>		6
Clay, part covered.....	4	0
Shale and covered.....	11	0
Ore, very siliceous, <i>Lower Mercer</i>		3
Shale, dark.....		3
Coal blossom, <i>Middle Mercer</i>		6
Clay, siliceous.....	2	0
Sandstone, shaly.....	4	4
Ore, kidney, local.....		2
Shale, gray.....	1	8
Coal and bone shale, <i>Flint Ridge</i>		6
Clay, light, plastic, very siliceous.....	2	0

Local deposits of Sand Block ore are present along the ridges in eastern and central Jackson Township. Near Otterbein Chapel in Section 9, this member, 4 inches thick, was exposed along the road. The elevation of the deposit is about 1,050 feet. Its position here is directly above the Upper Mercer coal, only a few inches thick, and 11 feet below the Upper Mercer member, represented by fossiliferous limestone and flint. Along the ridge in Section 10, the conditions are much the same except that the ore thickens to as much as 6 inches and the coal to 1 foot or more. Other exposures were observed in the southeastern part of the area.

The deposits appear to be thin and scattered in Richland Township and are not especially prominent in western Clinton. The member was formerly mined to a small extent in western Elk Township. The stratigraphic relation of the Sand Block ore to other members higher in the geological column is well shown in the following record taken along the road in central Section 7:

	Fr.	In.
Coal blossom, <i>Clarion</i>	1	0
Clay, plastic, light.....	5	0
Sandstone, light, soft.....	30	0
Coal blossom, <i>Winters</i>	1	0
Clay, plastic, light.....	1	0
Covered.....	3	0
Shale, part dark.....	3	0
Coal blossom, <i>Ogan</i>	1	0
Clay, plastic, light.....	2	8
Ore, nodules in clay.....		4
Shale and covered.....	21	6
Coal blossom, <i>Brookville</i>	1	6
Clay, plastic, light, lower part siliceous.....	5	0
Shale, gray.....	10	8
Ore, blocky, <i>Upper Mercer</i>		4

	Ft.	In.
Clay and covered.....	2	6
Sandstone, ferruginous, blocky.....	1	6
Shale, gray, siliceous.....	13	2
Ore, very siliceous, <i>Sand Block</i>		4
Shale, part dark.....	1	6
Coal blossom, <i>Upper Mercer</i>	1	0
Clay, plastic, light.....	2	0

In the vicinity of Elk Fork, the Sand Block ore, known locally as the "Dever block," was formerly mined at a number of places. The member here lies about 13 feet below the Upper Mercer or "Dunkel" ore which was worked very extensively throughout the area.

Economic value

The deposits of Sand Block ore in Vinton County are too thin and too lean to be of any special importance at present. Formerly also the member was regarded by the charcoal furnace operators as of less value than either of the associated Mercer ores as it was changed in a short distance from an ore of fair purity to one very rough and siliceous. Like most of the coal formation ores, it belongs to the foundry class, being high in phosphorus. The composition of the best Sand Block ore is approximately 25 to 40 per cent iron, .200 to .400 per cent phosphorus, and .50 to 1.50 per cent manganese.

BEDFORD COAL AND CLAY

The Bedford coal has fair continuity and is of some importance in central Ohio where in small fields in Muskingum, Coshocton, Holmes, and Tuscarawas counties, it is mined for a part of the local fuel supply. In Perry and Hocking counties, the member is more erratic in character and more uncertain in distribution. The most southern deposit that has been mined by drifting is in central Green Township of Hocking County. In southern Ohio or in Vinton, Jackson, Scioto, and Lawrence counties, the horizon is very poorly marked, as the member is in few places represented by more than a few inches of shaly coal and usually by only a soot streak of coal underlain by a thin stratum of impure clay. Further, in many localities both materials are wanting. The normal position of the Bedford coal is directly below the Upper Mercer limestone or its equivalents, black flint and iron ore. In Vinton County the average thickness of this coal is less than 1 inch and the maximum observed 6 inches. The associated clay is not only thin but siliceous and impure. The mean measurement is about 1 foot. As the Bedford members in the area have no economic value and little stratigraphic interest and as sections showing their relations

to other beds are given elsewhere, this coal and clay will not be considered further.

UPPER MERCER LIMESTONE, FLINT, AND IRON ORE

Stratigraphy and extent

The limestone now bearing the name Upper Mercer was described in 1858 by Rogers of the First Pennsylvania Survey as the Mahoning from exposures along the Mahoning River near Newcastle in Lawrence County, Pennsylvania.¹ The deposits there examined consist of a hard, blue limestone and black flint accompanied by iron ore. Twenty years later, or in 1878, the name was changed by White to Upper Mercer as the bed was traced by him to Mercer in Mercer County, the type locality for the underlying Lower Mercer limestone.² In Ohio the stratum was first designated by Orton in 1878 as the Gore limestone from exposures near Gore Furnace in Hocking County. In 1884 the name used in Pennsylvania was adopted in Ohio.

The Upper Mercer member represented in some form extends with only local wants across the State from Columbiana and Mahoning counties on the north to Scioto and Lawrence counties on the south. In the northern part of the field in Columbiana, Mahoning, Stark, Wayne, Tuscarawas, and Holmes counties, the horizon is marked largely by a hard, blue limestone with or without flint nodules. Locally, however, the deposits are so flinty that the quantity of siliceous matter in them is greater than that of the calcareous component. But little iron ore is found associated with the limestone in this part of the field. In its extension southward into the central part of the State in Coshocton, Muskingum, Licking, Perry, and Hocking counties, the common material at this position in the geological column is a black flint, overlain occasionally with irregular lenses of gray flint or with thin deposits of iron ore. In southern Ohio in Vinton, Jackson, Scioto, and Lawrence counties, this stratigraphic unit is represented by iron ore with little or no flint or limestone. In general, the Upper Mercer member where traced across the State thus changes from hard, blue limestone to black flint and then to iron ore.

All three materials bear fossils of marine origin. The limestone yields a greater number of individuals and species than the flint and this in turn more than the iron ore. In typical exposures the Upper Mercer limestone is bluish-gray to dark gray, somewhat siliceous and ferruginous, and uniformly fine in texture. The bed is so broken by

¹Rogers, Henry D., First Pennsylvania Survey, Vol. II, Part I. pages 566-7.

²White, I. C., Second Pennsylvania Survey, Rept. Progress, Geology of Mercer County, page 36.

joint planes that along the outcrop it regularly separates into large rectangular blocks. The material is moderately resistant to solution by chemical agencies and to disintegration by physical means, and on this account the bed appears at the surface with considerable regularity. Both lithologically and chemically the Upper Mercer limestone closely resembles the Lower Mercer. In the main the flint appearing on this horizon is usually dark or even coal-black in color, due to the influence of carbon and other pigments. The purer material is vitreous, brittle, and lustrous, and breaks with a deep conchoidal fracture in any direction. It is very dense and solid, except for small irregular cavities distributed indiscriminately throughout the mass. These openings may be filled with quartz crystals or with ferruginous matter. Like the limestone, the flint bed is regularly divided by joint planes into blocks which, where exposed along the outcrop, are more or less shattered by a network of fine cracks caused by expansion changes. This material is only moderately fossiliferous. The Upper Mercer flint is similar in appearance to the Zaleski flint, except that the latter is freer from cavities, slightly deeper brown in color, and more resinous in luster. The Upper Mercer, the thickest and most persistent ore bed in the Pottsville formation of southern Ohio, changes from a red or brownish yellow limonite on the outcrop to a bluish-gray siderite under deep cover. The bed is well stratified but is regularly broken by joint planes into variously shaped blocks. For these reasons the ore was named by the miners the Big Red Block. As it was the main reliance of Franklin Furnace in Scioto County, it was called by Brown the Franklin Block ore. The member is only sparingly fossiliferous.

The Upper Mercer is the most persistent and widely distributed ore in Vinton County and during the days of the charcoal furnaces it was more extensively mined than any of the other beds. It is present with some wants in northwestern Madison, western Brown, Swan, eastern Jackson, eastern Richland, Elk, and western Clinton townships. Flint or limestone accompanies the ore in a few places. The position of the member is, on the average, about 40 feet above the Lower Mercer limestone, 31 feet below the Putnam Hill limestone, and 54 feet below the Zaleski black flint, which are the main benches for reference. Considerable variations and irregularities, however, are found locally in these intervals. From more than 50 measurements, the mean thickness of the bed is 7 inches, the minimum 1 inch and the maximum 3 feet 7 inches. Generally the ore is present in a single bed but locally it may be divided into two, three, or even more distinct strata, varying in both composition and texture.

Brown Township.—Along Raccoon Creek and Twomile Run in northwestern Brown Township, the Upper Mercer member is gen-

erally thin and in many localities it is wanting. Such deposits were mined in but few places.

Madison Township.—The Upper Mercer is due close to drainage level along Raccoon Creek near Zaleski and along Strong Run in northeastern Section 36. Near the forks of the hollow in the latter area, this limestone and ore were exposed in the stream bed. The record secured is given below:

		Ft.	In.
Shale, gray, fossiliferous.....	} <i>Putnam Hill</i>	1	0
Limestone, shaly, fossiliferous.....			9
Coal.....	} <i>Brookville</i>	1	2
Clay, dark.....			4
Coal.....		1	3
Clay, plastic, light.....		3	6
Shale and covered.....		11	6
Ore, nodular, reddish-brown.....	} <i>Upper Mercer</i>		4
Limestone, shaly, blue, fossiliferous....			8
Limestone, hard, blue, blocky, fossiliferous.....			7

The ore varies from a soft limonite to a hard siderite, depending on the state of weathering. The limestone affords fair collecting as the fossils are well preserved.

Swan Township.—The Upper Mercer ore was extensively mined for many years in Swan Township, especially in the southern and western portions. Most of it was loaded for shipment at Creola. In some of the deposit the ore is very rich and is much above the average in thickness. The usual measurement of the bed, however, is between 4 and 8 inches.

Near Orland, the member is generally thin and locally wanting. Where observed in the southwestern part of Section 9, the deposit consists of 2 to 4 inches of iron ore underlain by 4 to 8 inches gray to dark, fossiliferous flint. Its position is about 960 feet above tide. Many old benches show where the ore was mined along the ridges in sections 5, 6, 7, and 8. Near the road forks in eastern Section 6, at an elevation of 1,010 feet, the deposit is made up of 5 inches of block ore underlain by 4 inches of rough, flinty ore. A record, taken just across the county line in southwestern Section 31, Washington Township, Hocking County, shows exceptionally well the composite nature of the member in places and also its stratigraphic relation to other well-known beds. The measurements are given below:

	Ft.	In.
Shale, gray.....	18	0
Shale, calcareous, very fossiliferous, <i>Putnam Hill</i>	1	8
Shale, dark, carbonaceous, <i>Brookville</i> coal horizon.....	1	1
Clay, dark, plastic.....	2	0
Shale, gray.....	3	4

	Ft.	In.
Shale, block.....		1
Coal.....		1
Clay, light.....	1	6
Shale, gray.....	6	4
Coal, shaly.....	}	8
Shale, with thin coal bands.....		8
Coal, shaly.....		0
Clay, light, plastic, siliceous.....	3	4
Sandstone and sandy shale, light.....	7	0
Ore, kidney.....	}	3
Sandstone, shaly.....		3
Ore, blocky.....		5
Ore, shelly.....		7
Limestone, blue, fossiliferous.....		9
Shale, siliceous.....		11
Flint, black.....		5
Shale, siliceous.....	7	8
Coal.....	}	3
Sandstone.....		2
Shale, coaly.....		5
Clay, impure, siliceous.....	1	6
Sandstone, shaly.....	6	4
Shale, dark, carbonaceous, <i>Upper Mercer</i> coal horizon.....		6
Clay, light, siliceous.....	2	6
Shale, gray, siliceous.....	6	0
Ore, kidney, <i>Lower Mercer</i>		2
Shale, gray.....		8
Shale, dark, carbonaceous, <i>Middle Mercer</i> coal horizon.....		6
Sandstone, hard, dark.....		2
Clay, light, siliceous.....	2	7
Shale, dark, carbonaceous, <i>Flint Ridge</i> coal horizon.....		4
Sandstone, hard, dark.....		3
Shale, dark.....		3
Clay, light, plastic.....	3	0
Shale, gray, soft, part siliceous.....	15	2
Shale, dark.....		5
Coal, hard, <i>Lower Mercer</i>	1	8
Clay, plastic, light.....	1	0
Shale, gray, part covered.....	4	4
Shale, dark, siliceous.....		10
Shale, gray, siliceous.....	2	0
Sandstone, massive, <i>Massillon</i>	25	0
Covered.		

Extensive mining by benching has been done along the ridge northwest of Creola in sections 19, 20, 29, and 28, where the ore is reported to be above the average in both thickness and quality. Locally it is underlain by black flint from a few inches to more than 1 foot thick. Many stripping operations are yet evident along the ridge in sections 31, 32, and 33, where the ore is reported to vary from 2 inches to 1 foot 10 inches in thickness. On the hill just east of Creola in Section 34,

measurements show 6 to 10 inches of ore underlain by about the same thickness of dark flint. The deposit here has an elevation of 836 feet and lies 104 feet below the Vanport limestone. Along Raccoon Creek in the southeastern part of the area, the Upper Mercer member is generally thin and consists usually of ore alone. Near the road forks in east central Section 25, the bed lies 764 feet above tide and measures 3 inches in thickness.

Jackson Township.—Formerly the Upper Mercer member was mined at many places along the main ridges in the eastern and central portions of Jackson Township. It shows no unusual features. The ore is generally in one bench and 4 to 6 inches thick. Locally it is underlain by black flint or cherty sandstone.

Along the ridge in western Section 10, both ore and black flint are present at an elevation of about 1,060 feet. Similar deposits were observed north of the Browns School in Section 9 and also in northeastern Section 16. Near the road forks in central Section 21, 4 inches of Upper Mercer ore was exposed at an elevation of 1,050 feet. South of the Shively School in Section 23, the member is divided into 3 to 5 inches of block ore and 4 to 6 inches of black flint. The bed lies 990 feet above tide. On the George W. Hartley farm in southwestern Section 36, the following rocks were exposed for measurement:

	Ft.	In.
Shale, dark, very fossiliferous, <i>Vanport</i>	2	0
Coal, somewhat bony	1	1
Clay shale		7
Coal	1	9
Clay		1
Coal		8
Clay, plastic, light	6	6
Covered	24	6
Limestone, very fossiliferous, <i>Putnam Hill</i>		5
Clay, shale, and covered	30	7
Ore, kidney		2
Shale, very siliceous		5
Ore, blocky, siliceous, sparingly fossiliferous		7
Shale, very siliceous	1	1
Ore, siliceous		3

Near by the lower ore stratum changes to gray or black flint, 5 to 8 inches thick. Its position is about 45 feet above the Lower Mercer limestone which is well developed.

Richland Township.—A part of the ore supply for Cincinnati Furnace, later known as Richland, was drawn from the Upper Mercer member in the eastern and the central parts of Richland Township. As elsewhere the deposits show considerable variation in thickness, character, and structure.

Near the Pawpaw School in Section 1, the Upper Mercer member was mined extensively by stripping along the outcrop. The elevation of the deposits is approximately 920 feet. One to two benches of ore are present, the thickness of which is reported to be 3 to 10 inches. Locally the ore is underlain by flint or dark, ferruginous sandstone. The position of the Upper Mercer member in this locality is nearly 45 feet above the Lower Mercer limestone, 40 feet below the Zaleski black flint, and 65 feet below the Vanport buhrstone. The thickness of the ore where observed in central Section 12 is from 4 to 6 inches, at the Wyckoff Crossroads in Section 15 from 3 to 5 inches, and along the ridge in sections 16 and 21 the measurements are about the same. Near the Dolly School in Section 22, 3 to 5 inches of block ore is accompanied by 3 to 10 inches of black flint. At this place the elevation of the bed is 925 feet above tide and its position about 35 feet above the Lower Mercer ore. Deposits similar in character and thickness were noted also in sections 27, 28, 32, 33, 34, and 3, south.

Elk Township.—The Upper Mercer ore is moderately persistent in Elk Township and is present above drainage in all but a few sections in the southeastern portion. The most extensive mining was done in the northern and western parts, the ore being hauled to the railroad at McArthur and Elk Fork.

Along the road in southeastern Section 3, the Upper Mercer ore is present at an elevation of 794 feet. The bed measures about 3 inches in thickness but near by it is reported to expand to as much as 8 inches. Formerly this ore was mined at a number of places in sections 4, 5, 6, and 7. The thickness observed is from 2 to 7 inches. Its relation to other members is well shown in the following record taken along the road in southeastern Section 8:

	Ft.	In.
Shale, gray.....	8	0
Shale, gray, fossiliferous, <i>Putnam Hill</i>	2	0
Coal blossom, <i>Brookville</i>	2	8
Clay, light, plastic.....	3	0
Sandstone, light, argillaceous.....	10	0
Covered.....	5	9
Ore, blocky, 3 to 5 inches, <i>Upper Mercer</i> , elevation 870 feet.....		3
Shale and shaly sandstone.....	14	7
Clay shale, dark.....	1	0
Coal, blocky, <i>Upper Mercer</i> or <i>No. 3a</i>		5
Clay, dark, siliceous.....	2	0
Shale and covered.....	6	4
Ore, siliceous.....		7
Shale, gray, parts siliceous.....	18	1
Shale, fossiliferous, <i>Lower Mercer</i>	1	0

West of McArthur the ore locally has fair thickness and was mined at a number of places. Several exceptionally good deposits in the

vicinity of the Hawk School were worked for shipment to furnaces in the Hocking Valley. Along the road in the northeastern corner of Section 26, the member is composed of two ore benches, of 3 and 4 inches respectively, separated by 8 inches of shale and underlain by a hard, ferruginous sandstone which locally changes to black flint. The bed lies 710 feet above tide. Locally along Elk Fork in this section, the ore is reported to thicken to 1 foot and to be of good quality. (See analysis, page 150.)

Clinton Township.—Both Hamden and Cincinnati furnaces drew a part of their ore supply from the Upper Mercer member in the western half of Clinton Township. This bed extends eastward to Dundas and Hamden Furnace before it disappears below the valley floors. Some of the deposits were far above the average in thickness and were mined extensively by stripping along the outcrop.

In sections 5, 6, and 7, the bed appears to be thin and in places wanting. On the Craig farm in Section 8 the deposits are much above normal in both thickness and quality and were stripped to deep covering. Measurements of the ore and associated rocks are given below:¹ (See analysis, page 150.)

	Ft.	In.
Soil.....	4	0
Shale, light gray.....	2	6
Sandstone, soft, ferruginous.....	2	3
Clay shale, gray.....	1	2
Shale, dark blue, sandy.....		6
Ore, limonitic, red, 10 inches to 1 foot..	} <i>Upper Mercer</i>	10
Ore, sideritic, blue.....		5
Coal.....		1
Clay.....		1
Sandstone.		

The few exposures observed in sections 17 and 18 show 2 to 5 inches of block ore, usually of inferior quality. West of Hamden in Section 19, considerable stripping was also done on the Robbins farm where the deposit consists of two benches of ore of 6 and 9 inches respectively and where it lies about 40 feet above the Lower Mercer limestone. Near Hamden Furnace the member is locally well developed and was used for iron smelting. The following record, taken along the old road in north central Section 28, shows very well not only the thickness and structure of the ore but also its relation to other important stratigraphic units:

	Ft.	In.
Shale and covered.....	10	0
Sandstone and covered.....	46	0
Coal blossom, <i>Middle Kittanning</i>	2	0

¹Geol. Survey Ohio, Report of Progress, 1870, p. 121.

Clay, light, plastic.....	1	0
Shale, shaly sandstone, and covered.....	25	0
Clay, plastic.....	3	0
Clay, flint.....	1	0
Coal blossom, <i>Lower Kittanning</i>	1	0
Clay and covered.....	6	0
Shale and covered.....	11	0
Limestone, <i>Vanport</i>	3	0
Covered.....	2	0
Coal blossom, <i>Clarion</i>	3	0
Clay, light, plastic.....	6	0
Sandstone, light, clay-bonded.....	7	8
Coal, weathered.....	2	2
Clay.....		3
Coal, weathered.....		5
Clay, plastic, dark.....	3	6
Shale, gray, siliceous.....	13	6
Ore, irregular, local.....		6
Shale, gray.....	7	2
Coal, <i>Newland</i>		5
Clay, light, siliceous.....	1	6
Sandstone, soft, parts covered.....	43	11
Ore, with shale layers..		10
Ore, blocky.....		7
Sandstone, ferruginous..		5
Ore, soft, siliceous.....		8
Ore, blocky.....		10
Shale, ferruginous.....		6
Sandstone, argillaceous.....	1	6
Shale and covered.....	4	0
Coal, bony.....		4
Clay, siliceous, upper part with coal bands.....	1	8
Sandstone, soft, massive, part covered.....	50	8

At other places in this vicinity the ore measures 4 to 10 inches in thickness. Locally it is underlain by an irregular stratum of black flint.

Economic value

Although of little value at present, the Upper Mercer ore in Vinton County was formerly an asset of importance as it was worked for many years over a wide area. Mining activity began with the advent of the charcoal furnaces within the county in 1852 and continued briskly until 1888 when the native ores were largely replaced by those from the Great Lakes region. Upper Mercer ore was used extensively during their active periods in Richland, Hamden, and Vinton furnaces and in less amounts in Zaleski, Eagle, and Hope. Later large quantities of ore were shipped from McArthur, Elk Fork, and Creola to outside furnaces, Creola being the main center for this trade. Regarding the ore shipped from this place, Mr. A. B. Kirkendall states:¹

¹Personal letter from A. B. Kirkendall, Creola, Ohio, Jan. 4, 1924.

"From 1880 to 1888 ore, both raw and calcined, was constantly being loaded at Creola. For months at a time the standing orders were for 25 cars per day which amounted to between 300 and 400 tons. One large pile on the yard in 1884 contained 19,000 tons. In the most active years from 1881 to 1884, the annual shipment was not far from 30,000 tons. The ore loaded here was largely block or Upper Mercer and was mined along the ridges west of this place. The bulk of the material was sold for smelting in the furnace at New Straitsville but some was shipped also to those at Winona, Gore, Orbiston, Buchtel, Greendale, and Floodwood. After 1888, the trade declined rapidly and soon ceased altogether."

Under deep cover the Upper Mercer ore is a siderite but along the outcrop, where affected by weathering, it is a limonite. These limonites smelted easily in the short stacks of the charcoal furnaces as they were open and porous. As the soft, oxidized ore was liked best for iron smelting, the main supply was obtained by stripping where the overburden was thin. The rule was that one foot of dirt could be removed for every inch of ore. Drift mining was not regularly practiced in Vinton County. From many observations, the mean thickness of the bed in this field is 7 inches but in local deposits the measurements range from 10 inches to as much as 3 feet and frequently average 1 foot 3 inches. Such a bed of ore will yield approximately 4,400 tons per acre.

The iron content of the Upper Mercer ore is low compared to that of the better grades from the Great Lakes district as the Upper Mercer is not only more siliceous and argillaceous but also much higher in combined water and volatile matter. When calcined the difference is not so great. The quality of the Upper Mercer ore is shown by the following analyses:¹

	No. 1	No. 2	No. 3
Moisture and ignition loss	7.50	33.38	8.75
Silica, SiO ₂	6.49	3.93	43.46
Ferric oxide, Fe ₂ O ₃	83.74	11.61	45.95
Ferrous oxide, FeO		43.51	.....
Alumina, Al ₂ O ₃	.70	.....	.00
Manganous oxide, MnO	trace	trace	.65
Lime, CaO	.07	2.30	.20
Magnesia, MgO	.14	2.95	.50
Phosphorus pentoxide, P ₂ O ₅	.217	.42	.971
Sulphur, S	.06	.03	trace
Total	98.917	98.13	100.481
Iron, Fe	58.62	42.00	32.17
Manganese, Mn	trace	trace	.50

¹Geol. Survey Ohio, Report of Progress, 1870, pp. 111 and 122.

	No. 1	No. 2	No. 3
Phosphorus, P.....	.073	.183	.424
Specific gravity.....	2.814	3.516	2.682

- No. 1. Limonite ore, upper part of bed, Craig mine, Section 8, Clinton Township.
 No. 2. Siderite ore, lower part of bed, Craig mine, Section 8, Clinton Township.
 No. 3. Limonite ore, siliceous, McAllister mine, Section 26, Elk Township.

The ores on the Upper Mercer horizon have a wide range in composition as they vary in the character of the ferruginous minerals from hydrated oxides to carbonates, and in the quantity of impurities such as sand, clay substance, and calcareous matter. In general, the ore in the upper part of the deposits is of better quality than that in the lower part and laterally the transition from good to poor ore may take place in a short distance. These ores are all in the foundry class as they are high enough in phosphorus to make an iron sufficiently fluid to pour well. The manganese varies from a trace to 1.00 per cent but usually averages about .50 per cent. In some deposits the content of lime and magnesia is such that it aids substantially, during smelting, in fluxing the siliceous matter. The weathered ore is generally low in sulphur. On the whole, the Upper Mercer, for a lean ore, has fair metallurgical properties.

TIONESTA COAL AND CLAY

The Tionesta coal and its associated clay are members of only local development in Ohio, being best defined in the central and the eastern parts of the field.¹ In Vinton County neither bed is present except in a few isolated places. Where observed the coal is represented only by a soot streak or by a few inches of carbonaceous shale and the clay by thin deposits of impure material. The position of the Tionesta coal is about 7 feet below the Brookville member. As they have no economic value, they will not be considered further.

BROOKVILLE CLAY

Stratigraphy and extent

The Brookville clay is widely distributed in Ohio, the main field extending from Mahoning County on the north to Scioto and Lawrence counties on the south. Throughout this wide expanse, this clay is generally of good quality and is mined extensively for ceramic purposes in Stark, Tuscarawas, Holmes, Muskingum, and Perry counties. The member is directly associated with the Brookville coal the position of which is just below the Putnam Hill limestone.

¹That is in Muskingum and Tuscarawas counties.

In Vinton County the Brookville clay is present in large or small areas in Brown, Swan, Jackson, Richland, Elk, Madison, and Clinton townships. It has been worked for the manufacture of ceramic ware only near McArthur in Elk Township. In the future, however, the deposits will probably become more important as the field is large and as much of it is easily available for such purposes. The position of the clay is directly below the Brookville or Newland coal and, on the average, about 24 feet above the Upper Mercer or Big Red Block ore. The material is everywhere a plastic clay with good bonding and working properties. It is usually somewhat siliceous in character but otherwise very free from detrimental impurities. From more than forty measurements, the mean thickness of the bed is 4 feet 6 inches and the variation from 1 to 7 feet.

Brown Township.—Upper Pottsville strata are found at the surface in the western half of Brown Township, but in this area the Brookville clay is regularly present only in the southwestern portion, elsewhere being absent or at least very poorly defined. In southwestern Section 32, the bed is 3 to 4 feet thick, the material of fair quality, and the deposits have an elevation of about 780 feet. In Strong Hollow in south central Section 31, the member is close to drainage level and where measured has the following thickness and relations:

		Ft.	In.
Shale, dark gray, fossiliferous	} <i>Putnam Hill</i>	1	0
Limestone, dark gray, shaly, fossiliferous			9
Coal	} <i>Brookville</i>	1	2
Clay, dark			4
Coal		1	3
Clay, plastic, siliceous, good, <i>Brookville</i>		3	6
Shale and covered		11	6

The member, 3 to 5 feet thick, is also exposed at an elevation of about 710 feet in central Section 25. It disappears below drainage along Raccoon Creek near Brewer Cut in Section 19.

Swan Township.—In Swan Township the Brookville members are nearly entirely absent, not through replacement but through lack of deposition. Thin local lenses of siliceous clay appear at only a few places in the southern part. Such deposits have no ceramic value.

Jackson Township.—The Brookville clay is due along all the main ridges in eastern Jackson Township but as a distinct unit it is present in only a few sections in the southeastern part. In southern Section 24, the bed is found at an elevation of approximately 960 feet and measures from 3 to 5 feet in thickness. The clay is siliceous in character but otherwise of fair purity. The conditions are similar in sections 25, 26, 35, and 36.

Richland Township.—The member has fair continuity in eastern Richland Township where it is present along all the main ridges. It is lacking, however, in development and quality, frequently being less than 2 feet thick and very siliceous in character. Near the Pawpaw School in Section 1, the Brookville clay is nearly 4 feet thick and the overlying coal about 1 foot. Where observed the clay measures 1 foot in central Section 11, 3 feet in southeastern Section 16, 1 foot 6 inches in western Section 28, 2 feet in northeastern Section 32, and 2 feet 6 inches along Jackman Ridge in Section 34. In the last named area the overlying coal is well developed and has been mined at a number of places.

Elk Township.—On the whole, in Vinton County, the Brookville clay as well as the accompanying coal is best developed in Elk Township. The bed has an average thickness of about 5 feet, is very free from damaging impurities, and is present above drainage in the entire area. This clay has been regularly used for a few years for ceramic products by the McArthur Brick Company at McArthur.

Along the road in southwestern Section 12, the clay is exposed at an elevation of 800 feet and has a thickness of 5 feet, and in adjacent areas the measurements are not far different. In the northwestern part of the township, the bed expands from 3 to 6 feet and the material is about standard in quality. The stratigraphic features are shown in the following record taken in south central Section 17:

	Ft.	In.
Coal and partings, <i>Winters</i>	2	11
Clay and covered.....	11	6
Shale, gray.....	6	0
Shale, weathered, fossiliferous, <i>Putnam Hill</i>		6
Coal blossom, <i>Brookville</i>	4	0
Clay, plastic, light, good, <i>Brookville</i> , elevation 870 feet....	4	0
Shale, gray.....	13	6
Shale, dark, plant fossils, <i>Bedford</i> coal horizon.....	1	0
Clay, dark, impure.....	2	6
Shale, siliceous.....	7	0
Sandstone, soft, part shaly.....	6	0
Clay, shaly, siliceous, <i>Upper Mercer</i>	2	0
Covered.....	19	0
Limestone, shaly, fossiliferous, part covered.....	5	0
Limestone, hard, fossiliferous.....		7

} *Lower Mercer*

The thickness of the clay where measured on the Margaret Morley farm in Section 20, and near the Hawk School in Section 30, is 5 feet. At McArthur the Brookville clay, which is obtained by stripping, is used in the manufacture of buff building brick. A section of the pit follows:

	Ft.	In.
Shale, gray.....	15	0
Shale, dark gray, very fossiliferous, <i>Putnam Hill</i>	2	6
Coal, <i>Brookville</i>	1	8
Clay, light, plastic, <i>Brookville</i>	5	2
Shale, gray, argillaceous.....	8	8
Sandstone, shaly.		

The clay is somewhat siliceous in character. That in the lower part of the bed is much higher in free silica than that in the upper part. It is free from iron oxide concretions and pyrite nodules. The deposit varies in thickness from 4 to 7 feet. Both the underlying and the overlying shales are used for brick making and are converted into a red building brick of good color and structure.

Where exposed along the road in southwestern Section 22, the Brookville clay is of good quality and measures 5 feet 6 inches in thickness. Deposits similar in development were also observed in northwestern Section 15, in northern and southern Section 14, and in central Section 23. At the coal mine of William Jacobs in Section 25, Elk Township, a sample of Brookville clay was taken for testing. Measurements of the strata there are given below:

	Ft.	In.
Shale, gray.....	10	0
Shale, dark gray, very fossiliferous.....	2	4
Limestone, dark blue, fossiliferous.....		7
Coal.....	1	3
Clay and bony coal.....		6
Coal.....	1	10
Clay, light, plastic, sampled.....	3	2
Clay, dark, plastic, sampled.....		8
Clay, very siliceous.....		0

The sample was taken under favorable conditions and is representative of the deposit. (For analysis see page 156.) In this locality the clay thickens to as much as 5 feet.

Madison Township.—Owing to the dip of the rocks to the east, the Brookville clay is above drainage only in small areas in Madison Township. It is exposed along Raccoon Creek in sections 34, 35, 29, 30, and 36, along the small stream in western sections 32 and 33, and along Elk Fork in sections 31 and 25. The deposits are somewhat uncertain in both thickness and quality. The overlying coal is generally well developed.

Along the abandoned road that leads from Raccoon Creek to the ridge east in Section 30, the Brookville members were well exposed in a gully cut by erosion. The clay here is only 2 feet 6 inches thick but near by it measures 4 feet. The overlying coal is thin and bony.

The main stratigraphic features are shown in the following record taken in central Section 29:

	Ft.	In.
Shale, dark.....	3	0
Coal.....	1	5
Clay.....	}	1½
Coal.....		
Covered.....		10
Clay, parts covered.....	5	0
Clay, shaly.....	3	6
Clay, dark, carbonaceous.....	2	0
Clay, part siliceous, light.....		4
Shale, parts covered.....	2	2
Shale, weathered, fossiliferous, <i>Putnam Hill</i>	22	6
Coal blossom, <i>Brookville</i>	2	0
Clay, light, plastic, good.....	1	0
Clay, light, siliceous.....	4	0
Clay, very siliceous.....	}	0
Shale, siliceous.....		
Sandstone, part shaly.....	1	6
Road forks, elevation 716 feet.	8	0
	22	0

An exposure of the Brookville member along the road in central Section 35 shows 3 feet 4 inches of light, plastic clay underlain by 3 feet of light, siliceous clay, and this in turn by 2 feet of light, argillaceous sandstone. The overlying coal is 1 foot 9 inches thick. On Wheelabout Creek the bed disappears below drainage in southern Section 29. In the western part of sections 32 and 33, the outcrop indications are that the member is about 5 feet thick and of good quality. In the vicinity of Vinton Furnace in Section 31, the deposits are somewhat erratic in thickness, varying from 2 to 5 feet. The Brookville member disappears below covering in eastern Section 25.

Clinton Township.—The Brookville clay appears above the valley floors in only the western half of Clinton Township. The member is generally present at the proper horizon but locally it is thin, siliceous, and impure. In the best deposits the material is well fitted for ceramic products but has not been used for such purposes.

Where exposed along the road in central Section 6, this clay measures 4 feet 10 inches in thickness, is of good quality, and lies 877 feet above tide. The overlying coal is thin and bony. Outcrop exposures observed in sections 5, 7, and 8 also indicate fair development. In central Section 29, the bed measures 5 feet in thickness but is somewhat siliceous in character. It is overlain by only 5 inches of Brookville coal. The position of the member is about 54 feet below the Vanport limestone. Near Hamden Furnace, the Brookville clay varies in thickness from 1 to 5 feet and in composition from a fat, plastic to a lean, siliceous material.

Economic value

In Vinton County the field in which the Brookville clay is most promising includes southwestern Brown, northwestern Madison, Elk, southeastern Jackson, eastern Richland, and western Clinton townships. The total area is about 80 square miles. However, through loss by erosion, replacement by other beds, and lack of development, only about half of this should be considered productive territory in which the thickness of the bed is 4 feet or more. The Brookville is everywhere a plastic clay rather high in bonding properties and is rather free from pyrite and concretionary matter. The common impurities are free silica and mica which are most abundant in the clay in the lower part of the deposits. The general properties, both physical and chemical, are shown in the following test made of a sample taken by W. Stout in November, 1923, at the mine of William Jacobs, which is located in northeastern Section 25, Elk Township:¹

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	.82	K ₂ O	.095	} Al ₂ O ₃ 1.00 {	SiO ₂ 2.268
Ignition loss.....	7.68	Na ₂ O	.013		TiO ₂ .041
Silica, SiO ₂	59.12	CaO	.007		P ₂ O ₅ .001
Alumina, Al ₂ O ₃	26.07	MgO	.022		
Ferric oxide, Fe ₂ O ₃	1.84	FeO	.064		
Lime, CaO.....	.20				
Magnesia, MgO.....	.57	RO	.201		
Titanic oxide, TiO ₂	1.06				
Phosphorus pentoxide, P ₂ O ₅	.04				
Sodium oxide, Na ₂ O.....	.34				
Potassium oxide, K ₂ O.....	2.48				
Sulphur, S.....	.04				
Total carbon, C.....	.24				
Inorganic carbon, C.....	.01				
True specific gravity.....	2.63				

Physical properties

Working properties: Plastic, smooth texture. Has excellent working properties through the machines without detrimental cracks or laminations.

Drying behavior: This clay dries with perfect safety under all conditions ordinarily obtained in the tunnel drier.

Drying linear shrinkage: 4.7 per cent.

¹Chemical analysis by D. J. Demorest of Ohio State University and physical tests by H. B. Henderson of the Standard Pyrometric Cone Co., Columbus, Ohio.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	2.1	14.78	Light buff
Cone 04	3.3	10.72	Light buff
Cone 02	4.3	7.96	Medium buff
Cone 1	4.3	7.83	Medium buff
Cone 3	4.8	6.96	Medium buff
Cone 5	4.9	5.31	Medium buff
Cone 7	5.1	3.67	Light gray buff
Cone 9	5.3	1.75	Light gray buff
Cone 11	5.0	1.78	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cones 02 to 11 (1,110 to 1,350° C. or 2,030 to 2,462° F.)

Total linear shrinkage at cone 7: 9.8 per cent.

Deformation temperature: Cone 30 (1,670° C. or 3,038° F.)

Possibilities: Intermediate heat duty refractories, face brick, hollow block, fire proofing, sewer pipe. This clay burns to a good clear color and has a long burning range.

The McArthur Brick Company at McArthur has successfully used the Brookville clay for a few years in the manufacture of high grade face brick. It is a siliceous, plastic clay with moderate refractory qualities; it works well through the machines, dries easily and safely in the tunnel drier, and has a long burning range with low shrinkage. The ware develops a clear golden buff color which is very attractive. Both smooth faced and rough textured wares are made.

In the main field in Elk, Madison, and Brown townships, the thickness of the overlying Brookville or Newland coal varies from 1 foot 4 inches to 4 feet but averages about 2 feet 6 inches. Both coal and clay may be mined from the same entry as the conditions are favorable for such work. The roof is a tough, shaly limestone and the floor a hard, argillaceous sandstone. In most of the area the accompanying coal, with fair economy, will furnish the fuel required for manufacturing the clay into ware.

The Brookville clay along the line of the Baltimore and Ohio Southwestern Railroad from Hope to Dundas and along that of the Hocking Valley Railway from Elk Fork to Dundas offers opportunities for the establishment of successful ceramic plants for the manufacture of a wide variety of ware. The associated coal is a good ceramic fuel and may be mined cheaply along with the clay. Shipping facilities, building sites, water, and labor are also at hand.

ALLEGHENY FORMATION

The important division of rocks overlying the Pottsville formation was defined in 1858 by Rogers of the First Geological Survey of Pennsylvania and called by him the Lower Coal Measures.¹ This name was regularly used until 1900 when O'Harra of the Maryland Geological Survey changed it to Allegheny formation, which term has been generally adopted in Pennsylvania, Maryland, Ohio, and West Virginia. This formation begins at the base of the Brookville or No. 4 coal and extends to the top of the Upper Freeport or No. 7 coal. The most important members of this formation are Brookville coal, Putnam Hill limestone, Clarion clay, Clarion coal, Vanport limestone, Ferriferous ore, Lower Kittanning clay, Lower Kittanning coal, Oak Hill clay, Middle Kittanning coal, Lower Freeport coal, and Upper Freeport coal. Other members of little importance are also present. The Allegheny formation of Ohio extends in a broad belt southwestward from the Ohio-Pennsylvania State line in Columbiana and Mahoning counties to the Ohio River in Scioto and Lawrence. The area covered is approximately 2,600 square miles. The thickness is variable but the usual range is between 175 and 280 feet.

The Allegheny formation is the most important division of rocks appearing at the surface in Vinton County as it contains the most valuable deposits of coal, clay, and limestone. Aside from these, shale, sandstone, flint, buhrstone, and iron ore are also present and have aided in the development of the region. The mean thickness of the formation is 236 feet. It is thinnest in the northern part of the county and thickest in the southern part. Rocks of this age are exposed in Brown, Swan, southeastern Jackson, eastern Richland, Elk, Madison, Knox, Clinton, Vinton, and Wilkesville townships.

¹Rogers, Henry D., First Geological Survey of Pennsylvania, Vol. II, Part 1, p. 16.

Section of the Allegheny formation in Vinton County

Formation	Member	General description	Thickness.	
			Ft.	In.
Allegheny...	Upper Freeport..	Coal, generally thin, often absent....	1	0
		Clay, plastic, impure.....	5	0
		Shale, gray.....	2	6
	Upper Freeport...	Limestone, nodular, fresh water.....		5
	Unnamed.....	Coal, everywhere thin, often absent..		1
	Bolivar.....	Clay, flint and plastic, irregular.....	6	0
		Shale, gray.....	9	9
	Upper Freeport...	Sandstone, largely replaced by shale.	18	0
	Lower Freeport...	Coal, only occasionally present.....		3
		Clay, plastic, impure.....	6	0
		Shale, gray, siliceous.....	12	0
	Lower Freeport...	Limestone, nodular, fresh water.....		6
	Lower Freeport...	Sandstone, often replaced by shale...	30	0
		Shale, gray, siliceous.....	5	0
	Middle Kittanning	Coal, persistent.....	2	6
		Clay, shaly, impure.....	2	0
		Shale and sandstone.....	22	0
	Strasburg.....	Coal, thin, local.....		2
	Oak Hill.....	Clay, flint and plastic, irregular.....	4	0
	Hamden.....	Ore, very local.....	3	0
		Shale, gray, siliceous.....	5	2
	Lower Kittanning	Coal, persistent.....	1	10
	Lower Kittanning	Clay, plastic, fair quality.....	7	0

Section of the Allegheny formation in Vinton County—Concluded

Formation	Member	General description	Thickness	
			Ft.	In.
Allegheny...		Shale and sandstone.....	22	6
	Vanport or Ferriferous.....	Ore, locally present.....		5
	Vanport.....	Limestone, gray, fossiliferous.....	4	7
		Shale, dark, carbonaceous.....	2	2
	Scrubgrass.....	Coal, locally present.....		11
		Shale, black, carbonaceous.....	4	9
	Clarion.....	Coal, persistent.....	3	2
	Clarion.....	Clay, flint and plastic, locally well developed.....	6	0
	Clarion.....	Sandstone, only locally well developed	10	0
		Shale, gray, siliceous.....	4	0
	Winters.....	Coal, locally with good thickness....	2	3
		Clay, plastic, poor quality.....	3	7
	Zaleski.....	Flint, gray to black, calcareous.....	1	2
		Shale, dark, siliceous.....	1	0
	Ogan.....	Coal, generally thin, often absent....		10
		Clay, plastic, fair purity.....	2	8
		Shale and sandstone.....	16	4
	Putnam Hill.....	Limestone and limy shale, fossiliferous	2	9
	Brookville.....	Coal, locally of value.....	2	5
		Total.....	235	8

BROOKVILLE COAL

Stratigraphy and extent

The Brookville or No. 4 coal, the basal bed of the Allegheny formation, was first recognized by Rogers in 1858 as a distinct unit in the coal fields of Jefferson and adjacent counties in western Pennsylvania.¹ From this region the stratum has been traced with a degree of certainty, by other geologists, westward and southward across Ohio into Kentucky. In Ohio a marine limestone, the Putnam Hill, lying directly above the Brookville member, has been a valuable guide in the correlation of the deposits on this horizon over a wide area. This coal throughout the Ohio field lacks the regularity of development of other beds higher in the formation but it extends with some wants and many impoverishments from Columbiana and Mahoning counties on the north to Scioto and Lawrence counties on the south. It is best represented in Stark, Wayne, Tuscarawas, Holmes, Coshocton, and Vinton counties. It has been mined in many localities for local fuel but in only a few places for railroad shipment.

In Vinton County the Brookville or No. 4 coal is locally known as the Newland seam as it first attracted attention on the Newland farm near McArthur. The member is due above drainage over a wide area across the central part of the county but, in some regions, especially in northern Brown and Swan townships, it is absent through lack of deposition. It is more regularly present in southwestern Brown, western Madison, Elk, southeastern Jackson, eastern Richland, and western Clinton townships. The deposits of most value are found near Zaleski in Madison Township, near McArthur in Elk, and on Jackman Ridge in Richland. The Brookville coal lies directly below the Putnam Hill member, represented in this area by shaly, fossiliferous limestone, by fossiliferous shale, or by both materials. Further, its position is, on the average, 29 feet above the Upper Mercer ore and flint, 26 feet below the Zaleski black flint, and 53 feet below the Clarion coal. The bed is very uncertain in thickness, expanding from 1 inch to as much as 5 feet 6 inches with an average from more than fifty measurements of 2 feet 5 inches of which 4 inches is clay parting. The Brookville member is also erratic in structure. In places it is represented by a single stratum of coal, elsewhere by two, three, or even more benches of coal separated by partings of clay, pyrite, or bone shale. The most persistent clay parting varies in thickness from 1 inch to 2 feet. Moreover lenses of hard, bony splint or impure cannel coal, usually between 2 and 8 inches thick, may appear in the lower and middle parts of the thicker deposits.

¹Rogers, Henry D., First Geological Survey of Pennsylvania, Vol. II, Part I, p. 490.

Brown Township.—In Brown Township the Brookville coal as a definite unit is present only in the southwestern part. Along Raccoon Creek and Twomile Run in the northwestern portion, it is absent or very poorly represented. On the property of M. M. Kasler near the mouth of Big Sandy Run, the coal was prospected by a shaft 28 feet deep and is reported to be about 4 feet thick. In the bed of Raccoon Creek, south of Brewer Cut, in Section 19, it has the following thickness and structure:¹

	Ft.	In.
Shale, calcareous, fossiliferous, <i>Putnam Hill</i>	3	0
Clay.....		1
Coal.....		10
Clay.....		5
Coal.....	1	6
Level of Raccoon Creek.		

In north central Section 25, the blossom of this coal is exposed along the road at an elevation of 710 feet. A small mine is operated on the Strong property in the southern part of this section, the entry being near the level of the Baltimore and Ohio Southwestern Railroad. A section in the mine is given below:

	Ft.	In.
Coal blossom, <i>Clarion</i>	1	0
Clay, plastic.....	3	0
Shale, sandstone, and covered.....	58	0
Shale, calcareous, fossiliferous, <i>Putnam Hill</i>	2	0
Coal, bony.....	1	0
Clay, plastic.....		7
Coal.....	1	9½
Clay.....		1
Coal.....		7½

The coal is mostly rough in appearance, due to the presence of thin, shaly partings. In Strong Hollow in southern Section 31, it is found near drainage level and has been mined in a small way. The upper bench of coal measures 1 foot 2 inches, the clay parting 4 inches, and the lower bench of coal 1 foot 3 inches. It is overlain by 1 foot 9 inches of fossiliferous shale and shaly limestone of the Putnam Hill member. Along the road in the southwestern part of Section 32, a thin coal blossom was observed at this horizon. The elevation of the deposit is 779 feet.

Swan Township.—No deposits of Brookville coal worthy of attention are present in Swan Township. In a few places in the southern part, the horizon is marked by thin lenses of shaly coal and carbonaceous shale. The associated Putnam Hill limestone member is also absent from the section.

¹Geol. Survey Ohio, Report 1870, p. 93.

Madison Township.—In Madison Township, the Brookville member is present above drainage along Raccoon Creek in sections 30, 36, 35, 29, and 34, along the small tributary of Elk Fork in sections 32 and 33, and along the main stream in sections 31 and 25. In this area the bed is persistent but is variable in thickness, structure, and composition. It has been mined in a small way at a number of places.

Along the abandoned road in southwestern Section 30, the Brookville deposit is made up of 1 foot of good coal underlain by 10 inches of bone coal and coaly shale, and is accompanied by 1 foot 9 inches of gray, fossiliferous shale of the Putnam Hill member. In Strong Hollow in Section 36, this coal has been mined at a few places by drifting. The deposit is about 3 feet thick and is regularly divided near the middle by a clay parting of 4 to 6 inches. Where observed in the central part of Section 35, the bed is free from deleterious matter and measures 1 foot 9 inches. East of this in the central part of Section 29, the member was well exposed in a gully at the side of the abandoned road. It lies near the foot of the hill at an elevation of approximately 760 feet. The measurements are 4 inches of coal, lower block, 4 inches of clay parting, and 1 foot 4 inches of coal, upper block. In the hollow south of Raccoon Creek in central Section 34, the Brookville member has been mined by stripping along the stream. The exposure shows the following strata:

	Ft.	In.
Shale, gray.....	5	0
Shale, gray, fossiliferous.....	2	4
Limestone, shaly, fossiliferous.....	}	5
Shale, gray, fossiliferous.....		5
Coal, good.....	}	10
Coal, very bony.....		6
Coal, rough.....		7
Clay, light to dark.....	3	5

The Brookville coal also appears in the stream bed at an elevation of about 800 feet in the west central part of the same section. Its position is 25 feet below the Zaleski black flint. The coal was mined rather extensively for a few years by the Mohio Coal and Mining Company in northwestern Section 32. At the head of the entry and under deep cover, a sample was cut in 1922 by the writer for testing. (For analysis see page 168.) The measurements are given below:

	Ft.	In.
Shale, gray.....	15	0
Shale, bluish-gray, very fossiliferous, <i>Putnam Hill</i>	3	6
Coal, bituminous.....	}	8
Sulphur band, rejected.....		1
Coal, bituminous.....		5
Clay, rejected.....		5
Coal, bituminous.....		10

	Ft.	In.
Coal, hard, splint type. .		9
Coal, bituminous.		7
Coal, hard, splint type. .	} <i>Brookville</i> , altitude 700 feet	1
Coal, bituminous.		9
Shale, bony.		$\frac{1}{4}$
Coal, bituminous.		2

The mine was dry and the coal cut from a clean, bright face. The sample is representative of the fuel in that area. Near the old stack of Vinton Furnace in Section 31, the exposure shows two benches of coal of 1 foot 1 inch and 10 inches respectively divided by 6 inches of bone shale. The elevation of the deposit is 785 feet. Just above the flood plain of Elk Fork in the south central part of Section 25, the Brookville member was prospected by a short entry and is reported to be 3 feet thick.

Elk Township.—The thickest and most persistent deposits of Brookville or Newland coal in Vinton County are found in Elk Township where the bed has long been mined for a part of the local fuel supply and also in a desultory way for shipment. As elsewhere the deposits vary greatly in thickness and in structure. The bed is usually divided into two coal benches by a clay parting and locally contains lenses of a hard splint or impure cannel coal. The thickness of the stratum varies from a few inches to as much as 7 feet.

Near the line in the east central part of Section 3, the Brookville coal is mined by drifting by F. L. King on the property of Harvey Alkire. A sample was cut by the writer in 1922 for testing. (For analysis see page 169.) The section of the coal is given below:

	Ft.	In.
Shale, fossiliferous, <i>Putnam Hill</i>	3	0
Coal, bituminous.		5
Coal, bony, rejected.		3
Clay shale, rejected.		$1\frac{1}{2}$
Coal, bituminous.		6
Clay, plastic, rejected.		5
Coal, bituminous.		$1\frac{1}{2}$
Coal, splint.	} <i>Brookville</i> , altitude 820 feet	$4\frac{1}{2}$
Clay parting, rejected.		$\frac{1}{2}$
Coal, bituminous.		7
Sulphur.		$\frac{1}{4}$
Coal, bituminous.		8
Coal, splint.		7
Coal, bituminous.	1	2
Clay, plastic.		

The sample was taken under good cover where the coal was bright and solid. The mine was dry. From reports the member has good thickness also along Raccoon Creek in central Section 2 where it was formerly

prospected by a short entry. Outcrop exposures in southwestern Section 12 show from 8 inches to 3 feet 2 inches of coal on this horizon. The stratigraphic relations of the Brookville to other members higher in the formation are shown in the following record taken along the road in southeastern Section 11:

	Ft.	In.
Sandstone, soft, massive.....	29	0
Coal blossom, <i>Clarion</i>	2	0
Clay and covered.....	6	0
Shale, gray.....	19	0
Coal, bony.....	}	7
Shale, black.....		7
Coal, good.....		2
Clay, impure.....		3
Shale, black.....		5
Coal, good.....		7
Clay shale.....	2	4
Coal, shaly.....		1
Clay, plastic.....		7
Flint, gray to black, <i>Zaleski</i>	2	11
Coal, bony.....	1	1
Shale, black.....	}	7
Clay, light, plastic.....		0
Coal, good.....		7
Clay, light, plastic.....	5	0
Ore, kidney.....		2
Shale, gray.....	10	10
Shale, gray, fossiliferous, <i>Putnam Hill</i>	3	0
Coal, with bone shale partings, weathered..	}	8
Clay, dark, plastic.....		11
Coal, bony.....		7
Clay, plastic, good.....	4	0

In the southern part of Section 14, the Brookville or Newland coal is about 3 feet thick but is very bony, and the entire bed is affected by thin shale partings. The deposits lie at an elevation of about 800 feet. West of this in Section 15, the member is also erratic in thickness and character. In the south central part of the section, it is mined for local trade by S. B. Ullom. Measurements of the coal are given below:

	Ft.	In.
Shale, fossiliferous, <i>Putnam Hill</i>	3	0
Coal, bituminous.....	}	5
Clay, plastic.....		6
Coal, bituminous.....		6
Coal, hard, splint.....	}	8
Coal, bituminous.....		5
Clay, plastic.....		0

Formerly the bed was worked at a few places east of McArthur in

Section 22. It is reported to be from 1 foot 6 inches to 3 feet thick. At the mines of the McArthur Brick Company in Section 27, it measures 1 foot 8 inches and is without partings. On the farm of Truman Dixon near by, the thickness of the lower bench of coal is 9 inches, the clay parting 1 foot 9 inches, and the upper bench of coal is 2 feet 1 inch. The coal in the lower block is bony but that in the upper one is of fair quality. At this place the position of the Brookville coal is 53 feet below the Clarion coal. On the property of William Jacobs in north-eastern Section 25, a wagon mine is operated for local trade. The thickness and structure of the member are shown in the record given below:

	Ft.	In.
Shale, gray.....	10	0
Shale, dark gray, fossiliferous.....	2	4
Limestone, shaly, fossiliferous.....		7
Coal, with thin layers of splint.....	1	3
Clay and bone coal....		6
Coal, part splint.....	1	10
Clay, plastic.....	4	0

Putnam Hill

Brookville, altitude 730 feet

In a prospect opening along the road in east central Section 36, at an elevation of 675 feet, the deposits consist of 10 inches of coal, lower block, 10 inches of clay parting, and 1 foot 3 inches of coal, upper block. The bed is overlain by the usual roof, the fossiliferous shale of the Putnam Hill member. In sections 4, 5, and 6, the deposits are thin and impure. The bed was mined at a few places in Section 7 and is reported to expand locally to as much as 4 feet. It has good thickness also in parts of sections 8 and 9. On the farm of Samuel Noble in central Section 17, the Brookville coal is regularly mined for local trade. This was formerly the Newland property, the type locality for the bed in this region, hence the local name Newland coal. The present mine is close to the original working. A sample was taken by the writer in 1922. (For analysis see page 169.) The section follows:

	Ft.	In.
Shale, fossiliferous, <i>Putnam Hill</i>	2	0
Coal, bituminous.....		8
Coal, bony.....		2
Clay, rejected.....		6
Coal, bituminous.....	1	0
Coal, hard, splint.....		8
Coal, bituminous.....	1	2
Shale and mother coal.....		$\frac{1}{4}$
Coal, bituminous.....	1	$3\frac{1}{2}$

Brookville or Newland

The sample was cut where the coal was bright and solid but it was somewhat moist as the mine was wet. At the abandoned Moore and Minton mine northwest of the above, the measurements are somewhat

similar. In sections 19 and 20, the bed is generally thin and uncertain. A small local mine is operated by Charles Dayton in the north central part of Section 30. The record secured is given below:

	Ft.	In.
Limestone, <i>Vanport</i>	6	0
Covered.....	10	0
Coal blossom, <i>Clarion</i>	2	0
Covered.....	24	7
Coal blossom, <i>Winters</i>	1	0
Clay and covered.....	7	0
Shale, gray, soft.....	8	0
Shale, coaly.....	1	0
Coal.....	1	10
Clay.....	} <i>Brookville</i> , altitude 925 feet	
Coal.....	1	5

Where exposed along the road, at an elevation of 900 feet, in the southeastern part of the same section, the lower coal bench, very shaly in character, measures 1 foot 9 inches, the clay parting 1 foot 8 inches, and the upper block of coal 1 foot 10 inches. The roof material is the gray, fossiliferous shale of the Putnam Hill stratum. In sections 28, 29, 31, 32, and 33, the coal is generally thin and has been mined at few places.

Richland Township.—In this township the Brookville coal is found along all the high ridges except those in the northwestern part. The member, however, is poorly represented except along Jackman Ridge in Section 34, where it has exceptional thickness and where it was formerly mined for local trade. Near the Pawpaw School, the bed is found at an elevation of 920 feet and is reported to be only 1 foot thick. The measurement is about the same on the Frank E. Farnsworth property in southeastern Section 2. No deposits of value were observed in sections 11, 12, 13, 14, 15, 16, 21, 22, 23, 24, 25, or 26. On the farm of William Nichols the Brookville coal was prospected by a small entry. About 2 feet of coal is exposed in the old opening above which is present 2 feet 3 inches of fossiliferous shale of the Putnam Hill member. The deposit lies near the top of the ridge at an elevation of 1,010 feet. South of the Jackman School in Section 34, on the John Jackman property, the following record was secured:

	Ft.	In.
Shale and covered.....	18	0
Ore, blocky, <i>Zaleski</i> member.....		8
Shale and covered.....	23	0
Shale, gray, very fossiliferous, <i>Putnam Hill</i>	4	0
Coal, <i>Brookville</i> , elevation 980 feet.....	5	1
Clay, siliceous.....	1	0

The coal in the middle part of the bed is a hard, bony splint and

that in the remainder of the bed is somewhat rough in appearance. Some pyrite nodules are also present. In this locality the bed varies from 2 to nearly 6 feet in thickness but elsewhere in the southern part of Richland Township it is generally thin. The member extends westward to the eastern part of Section 32 where it is present at an elevation of 1,015 feet.

Clinton Township.—The Brookville coal is of little importance in Clinton Township as it is everywhere thin and locally replaced by sandstone. It is present above drainage in the western half. An exposure along the road in central Section 6 and at an elevation of 892 feet shows 1 foot 6 inches of coal broken by thin, shaly partings. Other surface indications in this vicinity are even less promising. Along the valley west of Hamden Furnace, the member, where observed, varies in thickness from 4 inches to 1 foot 6 inches. The roof is fossiliferous shale, 1 to 4 feet thick. This coal has not been mined in a regular way at any place within the area.

Economic value

In Vinton County the deposits of Brookville or Newland coal of sufficient thickness and steadiness for drift mining are confined to local areas in southwestern Brown, northwestern Madison, Elk, and eastern Richland townships. The field is not large but it is ample in size to guarantee much fuel for future needs. In many of the thicker deposits two varieties of coal are usually present. The major portion of the bed is ordinary bituminous coal which is rather dull in luster and somewhat rough in appearance. Interstratified in this are thin lenses of hard, shaly coal which may be called, either an impure cannel, or a dense splint. It splits in thin slabs along closely spaced bedding planes. Concretions and thin laminae of pyrite are generally present but rarely abundant in the fuel. The Brookville is a highly volatile, non-coking coal, much resembling the Mercer members in most respects. The general quality of this fuel is shown by the analyses by Prof. D. J. Demorest and given below:

Sample of Brookville coal from the mine of the Mohio Coal and Mining Co., Section 32, Madison Township

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	66.01	69.03	Moisture.....	4.37	0.00
Hydrogen.....	4.85	4.56	Volatile matter.....	37.99	39.73
Oxygen.....	12.32	8.82	Fixed carbon.....	44.04	46.05

	As received	Moisture free		As received	Moisture free
Nitrogen.....	1.21	1.27	Ash.....	13.60	14.22
Sulphur.....	2.01	2.10			
Ash.....	13.60	14.22		100.00	100.00
	100.00	100.00			

Heating value

B. t. u..... 11,654 12,187

Calories..... 6,474 6,771

Fusion of ash, above 1,454° C. or 2,650° F.

Sample from F. L. King mine, Harvey Alkire Farm,
Elk Township, Section 3

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	66.45	70.75	Moisture.....	6.08	0.00
Hydrogen.....	4.83	4.42	Volatile matter.....	36.75	39.13
Oxygen.....	13.51	8.64	Fixed carbon.....	44.77	47.67
Nitrogen.....	1.16	1.23	Ash.....	12.40	13.20
Sulphur.....	1.65	1.76			
Ash.....	12.40	13.20			
				100.00	100.00
	100.00	100.00			

Heating value

B. t. u..... 11,628 12,381

Calories..... 6,460 6,878

Fusion of ash, incipient, above 1,454° C. or 2,650° F.

Sample from the mine of Samuel Noble in Section 17,
Elk Township

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	68.03	73.11	Moisture.....	6.95	0.00
Hydrogen.....	4.94	4.48	Volatile matter.....	38.49	41.36
Oxygen.....	15.21	9.71	Fixed carbon.....	45.81	49.24
Nitrogen.....	1.23	1.32	Ash.....	8.75	9.40
Sulphur.....	1.84	1.98			
Ash.....	8.75	9.40			
				100.00	100.00
	100.00	100.00			

Heating value

B. t. u..... 12,031 12,930

Calories..... 6,684 7,183

Fusion of ash, incipient, above 1,454° C. or 2,650° F.

The above tests show that the Brookville or Newland coal in Vinton County ranks rather low in quality. It is high in ash and volatile matter, low in fixed carbon and heating value, but the sulphur is not excessive. The ash is clay-like and fuses only at high temperatures. Owing to the large content of volatile matter, this coal burns with a long flame, which feature is desirable in firing some kinds of ceramic ware. It is used locally for domestic purposes and formerly was shipped for steam generation. Mining conditions are good as the roof everywhere is a tough, calcareous shale and the floor a rather siliceous clay. The development of the Brookville member will yield best results by working both coal and clay conjointly and by using the coal to manufacture the clay into a high grade ceramic product which will have a ready market over a wide area. Thus utilized the deposits offer substantial possibilities for increasing the wealth of the region.

PUTNAM HILL LIMESTONE

Stratigraphy and extent

The Putnam Hill limestone, named by Andrews in 1869, from exposures on Putnam Hill, near Zanesville, is purely an Ohio member. Up to the present time (1925) it has not been recognized by geologists either in Pennsylvania or in Kentucky. In Ohio the member is characteristically developed and very steady in a large interior field including parts of Stark, Wayne, Tuscarawas, Holmes, Coshocton, Muskingum, Licking, and Perry counties. South of this in Hocking and in northern Vinton counties, the bed is wanting or very feebly developed. It appears again, however, in southern Vinton and in Jackson counties in a modified form, that is, as deposits of calcareous shale and shaly limestone, both very fossiliferous and unlike the type material, chemically, physically, and faunally. The change in this part of the field has caused confusion in the correlation of both Putnam Hill and accompanying Brookville members.¹

The Putnam Hill member in Vinton County is present with some regularity in southwestern Brown, western Madison, Elk, eastern

¹In the report on Vinton County by Andrews (Report of Progress in 1870, pp. 92-126) the fossiliferous shale and shaly limestone on this horizon are, in some sections, rightly placed as the Putnam Hill and in others, incorrectly as the Blue or Lower Mercer member. These marine strata constitute the McArthur limestone of Morningstar (Bull. 25, pp. 116-129). The associated coal, locally called the Newland seam, was assigned by Orton (Vol. V, p. 159) to the Upper Mercer horizon. The same bed farther south in Jackson, Scioto, and Lawrence counties was called by Stout (Bull. 20) the Tionesta coal. The relations indicated by the present survey of Vinton County and adjacent areas is that the Putnam Hill limestone of central Ohio is correlative with the McArthur member of Vinton County and that the Brookville coal of the main basin is stratigraphically the same element as the Newland or Upper Mercer coal of Orton and the Tionesta member of Stout in the southern isolated portion of the field.

Richland, and western Clinton townships, but it is wanting or very impoverished in northern Brown, Swan, and eastern Jackson townships. The beds are of marine origin and bear an abundant fauna. In unweathered material the fossils are usually well preserved and easily collected. The thickness of the deposits varies from 2 inches to 10 feet but averages from more than 40 measurements 2 feet 9 inches. The most common material on the horizon is light to bluish gray, calcareous shale, which carries an abundant fauna of marine origin consisting largely of brachiopods and pelecypods. At the base of this stratum and just above the Brookville coal, lenses of shaly limestone also rich in fossil remains are locally present. In Vinton County the position of the Putnam Hill member is, on the average, 24 feet below the Zaleski black flint, 62 feet below the Vanport limestone, 31 feet above the Upper Mercer ore and flint, and 71 feet above the Lower Mercer limestone. It is of interest chiefly for its stratigraphic and paleontological features.

Brown Township.—The Putnam Hill member is largely wanting in the northwestern part of Brown Township but is very well defined in a few sections in the southwestern portion. It passes below drainage along Raccoon Creek in central Section 19. From 1 to 2 feet of fossiliferous shale marks the horizon along the road in Section 25 and along the stream in southern Section 26. In Strong Hollow in south central Section 31, the member is present at drainage level and consists of 9 inches of blocky, fossiliferous limestone, overlain by 1 foot of gray, fossiliferous shale. Similar deposits are present at an elevation of 780 feet in southwestern Section 32.

Swan Township.—In most of Swan Township, the Putnam Hill limestone and also the accompanying Brookville coal are absent or very poorly developed but local deposits were observed along Raccoon Creek in the southeastern part. In northern Section 36, the bed is present at an elevation of 780 feet and is about 1 foot 6 inches thick. It appears again at a few places along the ridge west of Creola in sections 31, 32, and 33. Near Hue in Section 6, the member outcrops along the ridge summit at an elevation of approximately 1,030 feet. The material is a calcareous shale, rich in fossil remains.

Jackson Township.—Owing to the rise of the rocks to the west, the Putnam Hill member in Jackson Township is confined to the ridge summits in the southeastern part. Few exposures were observed. Near the Curry School in northwestern Section 36, about 2 feet of fossiliferous shale is present at an elevation of 980 feet. The member extends northward along the high ridges in sections 26, 23, and 24.

Richland Township.—The Putnam Hill member is not especially prominent in eastern Richland Township but where present the deposits

are typical in character and normal in position. In central Section 1, it consists of 5 inches of shaly limestone overlain by 1 foot or more of very fossiliferous shale. Its position is 15 to 25 feet above the Upper Mercer ore and about the same distance below the Zaleski black flint. An outcrop of this fossiliferous shale, 2 feet thick, was exposed at an elevation of 980 feet along the ridge in central Section 11. On the property of William Nichols in central Section 28, the following beds were exposed at the mouth of an old coal mine:

	Ft.	In.
Shale and covered.....	16	0
Shale, gray.....	8	0
Shale, dark, very fossiliferous, <i>Putnam Hill</i> , elevation 1,010 feet.....	2	3
Coal, <i>Brookville</i> , part exposed.....	2	0

Along Jackman Ridge southeast of the above, the member is persistent and locally very thick. Near the school the measurements show from 6 to 8 inches of shaly limestone overlain by 2 to 4 feet of gray, calcareous shale. In both materials the fossils are abundant and well preserved. The elevation of the deposits is about 985 feet.

Elk Township.—The Putnam Hill marine stratum as well as the accompanying Brookville coal is more persistent and better developed in Elk Township than in any other part of Vinton County. It is above drainage in the entire field. The following record, taken along the road in southwestern Section 12, shows the stratigraphic relations of the Putnam Hill to other members in the upper part of the Pottsville and the lower part of the Allegheny formations:

	Ft.	In.
Allegheny formation		
Sandstone and covered.....	30	0
Coal blossom, <i>Clarion</i>	3	0
Clay and covered.....	6	0
Shale, shaly sandstone, and covered.....	29	6
Coal, weathered, <i>Winters</i>		6
Clay, light, plastic.....	2	0
Shale, dark.....	3	9
Coal, block, <i>Ogan</i>		3
Clay, dark, very siliceous.....	1	0
Sandstone, light, argillaceous.....	2	0
Shale, part dark.....	17	6
Shale, very fossiliferous, <i>Putnam Hill</i> , elevation 795 feet	1	6
Coal blossom, <i>Brookville</i>		8
Pottsville formation		
Clay, plastic, light to dark.....	5	0
Sandstone, light, clay-bonded.....	4	0
Sandstone, yellowish, clay-bonded.....	1	6
Shale, dark.....	5	8
Ore, block, <i>Upper Mercer</i>		2
Shale, siliceous.....	12	8

	Ft.	In.
Ore, dark, siliceous, <i>Sand Block</i>		3
Shale, dark.....	1	9
Coal, <i>Upper Mercer</i>		5
Clay, light, siliceous.....	4	11

On the hill north of this the fossiliferous shale of the Putnam Hill member is 3 feet 6 inches thick and is underlain by nearly 3 feet of coal. The member is also well developed in sections 11, 10, and 2. In north central Section 14, it consists of 6 inches of shaly limestone and 3 feet 2 inches of calcareous shale, both extremely fossiliferous. The deposit lies along the road near the foot of the hill and at an elevation of 800 feet. At the Moore and Minton mine in the north central part of Section 17 the following relationships are revealed:

	Ft.	In.
Shale.....	3	4
Coal.....	1	3
Clay.....		1
Coal.....		9
Clay.....		$\frac{1}{2}$
Coal.....	1	1
Covered.....	10	0
Shale, yellowish.....	6	0
Shale, blue.....	2	0
Shale, blue, siliceous.....	4	6
Shale, blue, fossiliferous.....	4	1
Limestone, shaly, blocky, fossiliferous..		10
Coal, good.....		$10\frac{1}{2}$
Coal, hard, splint.....		$5\frac{1}{2}$
Clay shale.....		5
Coal, shaly.....		7
Coal, good.....	3	2
Clay, plastic, siliceous.....	2	0
Sandstone, shaly.....	4	0

In this locality the position of the Putnam Hill member is 64 feet above the Lower Mercer limestone and 65 feet below the Clarion coal. From observations the member is steady in the western part of the township in sections 5, 6, 7, 8, 18, 19, 20, 30, 29, 31, and 32. At the mines of the McArthur Brick Co. at McArthur, this fossiliferous shale measures on the average about 2 feet 6 inches and the underlying coal 1 foot 8 inches. The gray shale lying above the Putnam Hill stratum is used in the manufacture of vitrified building brick. On the property of Truman Dixon in northwestern Section 27, the following beds were exposed for measurement:

	Ft.	In.
Shale, gray.....	5	0
Limestone, gray, fossiliferous, <i>Vanport</i>		8
Shale, dark.....		4

	Ft.	In.
Coal.....		11
Clay.....		6
Coal.....	1	6
Shale.....		2
Coal.....	1	5
Shale, sandstone, and covered.....	39	0
Shale, gray.....	5	0
Shale, gray, very fossiliferous, <i>Putnam Hill</i> , altitude 795 feet..	4	0
Coal, fair.....	2	1
Clay, dark.....	1	9
Coal, bony.....		9

At the mine of William Jacobs in northeastern Section 25, the member is also well represented, consisting of 7 inches of shaly limestone and 2 feet 4 inches of calcareous shale, both materials bearing an abundant fauna. It is equally well developed in the eastern part of Section 36.

Madison Township.—Owing to the eastward dip of the rocks, the Putnam Hill member passes below drainage along the streams in the western part of Madison Township. The physical and stratigraphic features observed here are much the same as they are in Elk Township to the west. Along Strong Hollow in northeastern Section 36, the member is present not far above the valley floor and consists of both shaly limestone and calcareous shale. The bed, 1 foot 9 inches thick, was well exposed along the abandoned road in southwestern Section 30, has an altitude of about 755 feet, and lies 30 feet below the Clarion coal and 102 feet below the Lower Kittanning member. Similar deposits outcrop along the hills facing Raccoon Creek in sections 29 and 34. The bed appears just above drainage in southwestern Section 33 and in northwestern Section 32. Just east of the old stack of Vinton Furnace in Section 31, the following record was obtained:

	Ft.	In.
Limestone, <i>Vanport</i>	2	0
Covered.....	10	0
Shale, gray.....	11	3
Coal and partings, <i>Clarion</i>	4	9
Covered.....	14	0
Sandstone, massive.....	15	0
Coal, bony, <i>Winters</i>		11
Clay, plastic.....		9
Shale, dark.....		8
Coal, fair, <i>Ogan</i>		5
Clay and covered.....	2	0
Sandstone and covered.....	18	3
Shale, gray.....	7	7
Shale, gray, fossiliferous, <i>Putnam Hill</i> , altitude 790 feet.....	2	0
Coal, shaly, weathered.....	1	6
Coal shale, dark.....		6

	Ft.	In.
Coal, weathered.....		10
Shale, bony.....		6
Coal, weathered.....	1	1
Clay, light, plastic.....	2	0
Sandstone, light, clay-bonded.....		8
Sandstone, shaly.....	8	0

The position of the Putnam Hill member in this locality as thus measured is 62 feet below the Clarion coal and 88 feet below the Vanport limestone, which are the best benches for reference. The stratum passes below the bed of Elk Fork in the eastern part of Section 25.

Clinton Township.—The Putnam Hill marine limestone is due above drainage along all the larger streams in the western half of Clinton Township but in parts of the area the bed is replaced by sandstone. Where present the member is generally thin and consists largely of calcareous shale. But few deposits were observed along the ridges in sections 5 and 6. This member is present at an elevation of 840 feet in western Section 16, at 850 feet in central Section 29, and at 815 feet near Hamden Furnace in Section 28.

Economic value

The Putnam Hill member in Vinton County is not a true limestone but more a calcareous shale, rich in fossil remains. Locally the lower part of the bed is rather hard and blocky and may be called an impure, shaly limestone. In this part the content of calcium carbonate is 30 to 50 per cent, most of the CaCO_3 coming from the shells of the marine fauna. The shale is low in such matter. The chief value of the member is that it contributes small quantities of lime to the soil on this horizon. The outcrop may often be detected by the abundance of blue grass and clover growing in such a residual soil. The member is of interest largely for its stratigraphic and paleontologic features.

OGAN COAL AND CLAY

Stratigraphy and extent

In southern Vinton and in northern Jackson counties a bed of gray to black flint makes its appearance in the Allegheny formation between the Putnam Hill limestone and the Clarion coal. The stratum seems to be confined to this local area as it has not been definitely recognized elsewhere in Ohio. The flint bears an abundant marine fauna. The deposits expand in thickness from 2 inches or less to 4 feet 6 inches or more. The flint is accompanied by two coal beds, one lying closely

above and the other directly or not far below the siliceous stratum. Both coals are underlain by clays which vary greatly in thickness and in character. The normal order of deposition in this local basin is therefore, clay, coal, flint, clay, and coal. Although closely spaced, the two coal beds are not depositionally related as they were laid down, not during one continuous swamp period, but during two periods which were separated by the marine invasion that gave rise to the flint stratum. Locally, however, the flint member is very thin or it even gives way to a few inches of siliceous shale in which case the two coal beds appear to be only separate benches of the same deposit.

In former reports the name Winters coal was given indiscriminately to that above the flint, to that below, or more commonly to both beds combined. It was thus designated on account of a prominent mine on the Winters farm located about one mile southwest of McArthur. For the coal lying above the flint stratum the name Winters is retained whereas for that found below this marine deposit the term Ogan is applied, as this member is not only well developed but its stratigraphic relations are definitely fixed on the Ogan farm in Section 14, Elk Township. The flint may conveniently be termed the Zaleski member for the thickest deposits are present west of this village.

The main field in which the Ogan coal is locally distributed includes southwestern Brown, southeastern Jackson, eastern Richland, Elk, western Madison, and western Clinton townships. The bed is uncertain in extent, erratic in character, and varies in thickness from a mere soot streak to about 3 feet with an average of not more than 10 inches. The bed may be either free from shale partings or much broken by such lenses. Its position is directly or closely below the Zaleski flint. The intervals to other well-known members are as follows: 24 feet to the Brookville coal, 53 to the Upper Mercer ore, 29 to the Clarion coal, and 40 to the Vanport limestone. The clay associated with the Ogan coal is of only fair quality. It is plastic in character and usually siliceous in composition. The deposits are uncertain in thickness, expanding from 1 to 5 feet or with an average of not more than 2 feet 8 inches. On the whole, this clay is of little importance. The Ogan coal and clay have fair development in the southwestern part of Brown Township. Their relations to other members are well shown in the following record taken along the road in southwestern Section 32:

	Ft.	In.
Sandstone, massive, soft, parts covered.....	56	0
Coal blossom, <i>Middle Kittanning</i> or <i>No. 6</i>	1	0
Clay, plastic.....	2	0
Shale and covered.....	19	0
Coal blossom, <i>Lower Kittanning</i> or <i>No. 5</i>	1	0
Clay, light, plastic.....	16	0
Sandstone, light, soft.....	16	0
Shale, gray, siliceous.....	15	0

	Ft.	In.
Covered.....	2	10
Coal blossom, <i>Clarion</i> or <i>No. 4a</i>	1	6
Clay, plastic, light.....	7	8
Shale, light gray, siliceous.....	10	0
Clay, light, plastic.....	1	6
Shale, light, siliceous.....	2	6
Sandstone, shaly, light gray.....	4	0
Shale, gray, siliceous.....	10	0
Coal sinut, <i>Winters</i>		1
Clay, siliceous, shaly.....	1	4
Flint, gray, 4 to 8 inches, <i>Zaleski</i>		6
Shale, dark.....		6
Coal, weathered, with shale partings, <i>Ogan</i>	2	8
Shale, dark.....	1	0
Clay shale and shale.....	8	0
Shale, very fossiliferous.....	1	0
Limestone, shaly, blocky, fossiliferous.....		5
Coal blossom, <i>Brookville</i> or <i>No. 4</i>		4
Clay, plastic.....	1	0

The Ogan coal is present but generally thin in sections 31, 26, and 25 of the same township. It is wanting in most of Swan Township, appearing only locally in the southern part as thin lenses of shaly coal or carbonaceous shale. In Jackson Township, the Ogan coal is present along the summits of the high ridges in sections 23, 24, 25, 26, 35, and 36. The coal is generally of fair quality but the thickest deposits measure not more than 1 foot. The conditions are much the same in Richland Township where the stratum was observed in sections 1, 2, 11, 12, 13, 24, and 32. The stratigraphic features are shown in the following record taken in the northern part of Section 1:

	Ft.	In.
Flint, light, <i>Vanport</i>	1	6
Shale, black.....	1	6
Coal blossom, <i>Clarion</i>	1	0
Clay, light, plastic.....	4	0
Covered.....	28	0
Coal blossom, <i>Winters</i>	2	0
Clay and covered.....	3	0
Flint, black, <i>Zaleski</i>	1	0
Shale, dark gray.....	1	6
Coal blossom, <i>Ogan</i> , altitude 990 feet.....	1	0
Clay, plastic.....	2	0

The Ogan, Zaleski, and Winters members are all better developed in Elk Township than in any other part of Vinton County and the type section for each is within the area. They have fair continuity but vary greatly from place to place in thickness, character, and arrangement. The coal beds only locally thicken sufficiently for mining. In general the Winters bed exceeds the Ogan in development. Locally the flint

stratum separating the two members is very thin or it even passes to a siliceous shale only a few inches thick. In this case the Winters and Ogan coals, divided by only a thin parting, appear as one deposit and hence are mined conjunctly.

In north central Section 1, the Ogan member outcrops in a ravine on the property of Mrs. H. J. Malone where it was mined by stripping. The structure and thickness are shown in the record given below:

		Ft.	In.
Flint, gray, shaly.....	} <i>Zaleski</i>	1	1
Flint, gray, irregular, 10 to 14 inches..		1	0
Coal, shaly.....	} <i>Ogan</i>		5
Clay shale, dark.....			3
Coal, bituminous.....			6
Coal, bony, cannel nature.....			4
Shale, coaly.....			$\frac{1}{2}$
Coal, bony, cannel nature.....			1
Coal, bituminous.....			9
Clay, siliceous.....		1	0

The Ogan coal at this place lies about 40 feet below the Clarion coal and 75 feet below the Vanport limestone. In sections 2, 3, 4, 5, 6, 7, and 8, the bed is generally thin, often decreasing to a mere soot streak. On the ridge west of Elk Fork in Section 9, the Ogan coal was formerly mined in conjunction with the Winters. In general in sections 10, 11, and 12, the thickness of the stratum is 3 to 10 inches and the overlying material gray or black flint of the Zaleski member. On the Ogan farm in Section 14, the following relations were observed:

		Ft.	In.
Coal blossom, <i>Winters</i>		2	0
Covered.....		3	0
Flint, massive, black, <i>Zaleski</i>		3	2
Coal.....	} <i>Ogan</i> , altitude 800 feet		8
Shale, dark.....			5
Coal.....		1	7
Shale and covered.....		19	0
Coal blossom, <i>Brookville</i>		2	0

Both the Ogan and the Zaleski members reach their maximum development in this vicinity, which should therefore be considered the type locality. Here the coal is not only persistent but is of fair thickness and quality and the overlying flint stratum, 1 to as much as 5 feet thick, presents all the variations from the gray, calcareous to the black, lustrous material and contains abundant fossils of marine origin. Other records west of this in the central part of the township show the same order of deposition but considerable variation in both thickness and character of the members. In the old Winters mine near McArthur, the Ogan coal is nearly 2 feet thick and is separated from the overlying

Winters coal by only 1 to 6 inches of shale and flint. The conditions are much the same east of the town except that the flint thickens locally to 1 foot or more. The stratigraphic relations of the various beds are well shown in the following record taken on the property of William Elliott in east central Section 26:

	Ft.	In.
Shale, dark.....	6	0
Coal.....	1	2
Shale.....		1
Coal.....		6
Shale.....		2
Coal.....	2	0
Clay, very siliceous.....	1	1
Flint, black, <i>Zaleski</i>	1	1
Shale, black, carbonaceous.....		5
Coal, blocky, <i>Ogan</i>		9
Clay, plastic.....	2	0
Covered.....	28	0
Coal blossom, <i>Brookville</i>	2	6

Winters

In Madison Township the Ogan coal is above drainage only in the western part along Raccoon Creek, Wheelabout Creek, and Elk Fork. The bed is everywhere thin and in places wanting. The overlying Zaleski member also shows impoverishment, changing from flint to iron ore and to siliceous shale. Likewise the Winters coal is variable and unsteady. These features with their stratigraphic relations are shown in the following record taken along the road southwest of Zaleski in central Section 35:

	Ft.	In.
Sandstone, massive, soft.....	50	0
Coal, bony, <i>Scrubgrass</i>		10
Shale, black.....	3	2
Coal, weathered.....	1	5
Shale.....		2½
Coal.....		7
Clay, dark.....	1	0
Clay, light, good.....	5	8
Clay shale.....	4	6
Shale, siliceous, gray.....	5	6
Clay shale, light.....		8
Coal, shaly.....		2
Clay, light, plastic.....	1	3
Coal and black shale.....		3
Clay, light, plastic.....	1	3
Coal, shaly.....		2
Clay, light, plastic.....	1	4
Shale, dark, with ore nodules, <i>Zaleski</i>		7
Coal, shaly, <i>Ogan</i> , altitude 796 feet.....		8
Shale, dark, carbonaceous.....		5
Clay, light, plastic.....	2	0
Clay, dark, part shaly.....	3	2

Winters

Clarion

	Ft.	In.
Clay shale, dark.....	3	0
Clay, light, siliceous.....	3	2
Shale, gray, upper part siliceous.....	16	2
Shale, gray, fossiliferous, <i>Putnam Hill</i>	3	0
Coal, rotten, <i>Brookville</i>	1	9
Clay, light, plastic.....	3	4
Clay, light, siliceous.....	3	0

South of Raccoon Creek in Section 34, the Ogan coal is more normal, varying from 4 to 10 inches in thickness, and is usually accompanied by 6 inches to 2 feet of flint. The deposits are similar in sections 33 and 32 but near Vinton Furnace in Section 31, they are thin, variable, and uncertain, indicating marginal deposition. The basin apparently does not extend far eastward or southward. These members are absent also as definite stratigraphic units in Vinton Township where they are due above drainage along Pierce Run from Oreton to Radcliff.

The Ogan member is moderately persistent in Clinton Township and is absent more through replacement by sandstone than through lack of deposition. The stratum is everywhere thin, less than 1 foot, and is usually overlain by flint or hard shale. Along the road in northwestern Section 16, the following rocks were exposed:

	Ft.	In.
Sandstone, massive.....	32	0
Coal smut, <i>Winters</i>		2
Clay shale.....		8
Shale with thin layers of black flint, <i>Zaleski</i>		6
Coal, rotten, <i>Ogan</i>		8
Clay, upper part dark, lower part siliceous.....	5	0
Sandstone, argillaceous.....	6	0

Deposits similar in character were observed in sections 15, 22, 23, 28, and 29. The overlying Zaleski member in places expands to more than 2 feet in thickness.

Economic value

The Ogan coal may be considered a fuel asset of only slight importance to Vinton County as the field is small and as the bed is thin in most places. The mean thickness in the main basin is about 10 inches and the maximum measurement nearly 2 feet 8 inches. At present (1925) the bed is not regularly worked at any place within the area but formerly it was mined by stripping or by drifting in a few localities for small supplies of domestic fuel. In general this coal is the ordinary bituminous but in a few deposits thin lenses of cannel coal are also present. From appearances the Ogan coal is of fair quality as it is moderately free from shale and pyrite impurities. It belongs to the

class of free-burning, high volatile fuels. In the thicker deposits the mining conditions are good as the roof is the Zaleski flint, solid and strong, and the floor a siliceous shale. Near McArthur the Ogan and Winters coals were mined conjointly as there they are separated by only a thin layer of siliceous shale or shaly flint.

The clay associated with the Ogan coal averages less than 3 feet in thickness but expands locally to as much as 8 feet. In general it is of poor quality, being siliceous in character and contaminated with concretionary matter. In conjunction with other clays and shales, it is used by the McArthur Brick Company at McArthur for the manufacture of a few grades of building brick.

ZALESKI MEMBER

Stratigraphy and extent

The most characteristic material on the Zaleski horizon is a black or brownish black flint, hard and lustrous. This rock breaks in any direction with a deep conchoidal fracture and with sharp edges. The coloring pigment appears to be most largely disseminated carbon. Like most dense strata in the coal formations, it is regularly divided by joint planes into rectangular blocks. The exposed material is traversed by a network of fine cracks due to expansion changes. Aside from the true flint, the horizon also yields calcareous flint, siliceous limestone, calcareous shale, and iron ore. In the limy varieties the color varies from light gray to grayish brown, the shade decreasing as the lime increases. The iron ore under deep cover is a siderite but near the surface this has been changed to a limonite. The calcareous flint and siliceous limestone are exceedingly fossiliferous whereas the hard flint and iron ore are only sparingly so.¹

In Ohio the Zaleski member with its associated Ogan and Winters coals has as yet been recognized only in southern Vinton and northern Jackson counties. The basin thus appears to be small, as now outlined, covering an area of not more than 130 square miles. The limits of such deposition to the north and to the south are well defined as these beds give way to shales and sandstones. To the east, before they pass under cover, they become thin and variable, indicating marginal conditions. To the west, however, a part of the original deposits has been lost by erosion. The evidence thus indicates that during early Allegheny time conditions for sedimentation were such that in this small basin two coal beds and a marine, calcareous flint were deposited whereas elsewhere in deeper water shale and sandstone were

¹See Black Flint member, Morningstar, Helen, Geol. Survey Ohio, Fourth Series, Bull. 25, pp. 130-138.

formed. These strata are best developed near McArthur, Zaleski, and Hamden.

The stratigraphic position of the Zaleski member is, on the average, about midway between the Brookville coal and the Clarion coal, or 26 feet above the Brookville and 27 feet below the Clarion. These intervals, however, vary much and erratically from place to place. The flint usually forms the roof of the Ogan coal and the floor for the clay of the Winters coal. The mean thickness of the Zaleski member from more than thirty measurements is 1 foot 2 inches but the variation is from a few inches to about 5 feet.

The Zaleski member is due above drainage along Raccoon Creek and Twomile Run in western Brown Township. The only deposits observed, however, are in sections 25, 31, and 32, where a thin stratum of flint or an iron ore is occasionally present. Likewise in Swan Township, the few irregular lenses are confined to the southern part.

In Jackson Township the Zaleski member, more persistent and distinctive, is confined to the main ridges in the southeastern part. In southern Section 24, the bed, at an elevation of 1,010 feet, is 4 to 10 inches thick. Near the Centenary Church in Section 23, the stratum outcrops near the ridge summits and was quarried rather extensively by the aborigines for various implements such as arrows, scrapers, drills, knives, and hoes. Some of the pits are yet quite distinct. Local deposits are also present in sections 25, 26, 27, 34, 35, and 36.

Owing to the dip of the rocks to the east, the Zaleski member is present only on the main ridges in eastern Richland Township. In this area the bed is uncertain in extent, thickness, and character. It varies from 3 inches to 1 foot 6 inches in thickness, and from a hard, dark brown, lustrous flint to gray, shaly material. The most noteworthy deposits are present in sections 1, 2, 11, 12, 13, and 24. Flint from this area was also used by the aborigines as several quarry pits are still (1925) evident in southeastern Section 2 and in central Section 11. Further, chipping grounds are found at many places along the ridges. The most western exposures are on the high knobs in Section 32, where the elevation of the bed is about 1,030 feet above tide and the thickness nearly 1 foot.

The shallow water conditions giving rise to the precipitation of siliceous matter by organic life, although widespread in Elk Township, were not continuous over the whole area, as some wants are apparent in the northern and southern portions. The deposits with maximum development are present near McArthur and east of Zaleski, in which areas the stratigraphic relations to other beds are also definite, thus fixing the position of the flint stratum in the geological column. Along the road in southwestern Section 12, the following rocks were exposed:

	Ft.	In.
Sandstone, friable, massive.....	35	0
Coal blossom, <i>Clarion</i>	2	0
Clay and covered.....	6	0
Shale, gray, with ore nodules.....	17	0
Coal, weathered, <i>Winters</i>	2	3
Clay and covered.....	3	0
Flint, gray to dark, <i>Zaleski</i> , altitude 823 feet.....	2	4
Coal, weathered, <i>Ogan</i>		10
Clay and covered.....	4	4
Shale, gray.....	2	0
Ore, irregular, local.....		4
Shale, gray.....	11	8
Shale, dark blue, fossiliferous, <i>Putnam Hill</i>	1	0
Coal and partings, weathered, <i>Brookville</i>	2	3

The Zaleski member at this place is very fossiliferous and it is somewhat calcareous in composition. Its position with reference to overlying and underlying members is about normal for this part of the township. The best developed deposits observed in the county are present on the Ogan farm in southeastern Section 14. Measurements taken here are given below:

	Ft.	In.
Coal, <i>Winters</i> , thickness on outcrop.....	1	7
Clay, siliceous.....	1	0
Flint, dark to gray, part calcareous, <i>Zaleski</i>	4	6
Coal, reported thickness, <i>Ogan</i>	2	0
Shale and covered.....	17	0
Coal blossom, <i>Brookville</i>	1	0

The material in this deposit varies from a calcareous flint to a siliceous limestone. It bears a large, well preserved, marine fauna and thus affords good collecting. Less than one-fourth mile west of the above exposure, the Zaleski member changes to a dense, black, lustrous flint more than 3 feet thick. In eastern Section 10, the stratum, represented by similar material and present at an elevation of nearly 880 feet, is less than 1 foot thick. The development is not far different in Section 15. In the western part of the township, the deposits are local and thin and the flint more shaly in character. Its relation to other members is shown in the following record taken in southern Section 19:

	Ft.	In.
Flint, irregular boulder, <i>Vanport</i>	1	6
Covered.....	5	0
Coal blossom, <i>Clarion</i>	1	0
Clay, light, plastic.....	5	0
Shale and covered.....	12	4
Coal blossom, <i>Winters</i>	1	0
Clay, siliceous.....		8
Flint, gray, irregular, <i>Zaleski</i> , altitude 940 feet.....		3
Coal blossom and dark shale, <i>Ogan</i>	1	0
Clay, siliceous.....	1	0

On the hill just east of McArthur, the Zaleski member outcrops at an elevation of about 860 feet. It is here a hard, dark flint, 6 inches to 1 foot 4 inches thick. Its position is just below the Winters coal, which formerly was mined for local needs, and 30 feet above the Brookville or Newland coal. The member is also present with fair development in local areas in sections 23, 26, 27, and 35.

In Madison Township the Zaleski member is above drainage only along Raccoon Creek, Elk Fork, and their minor tributaries in the western part. The bed is very unsteady, being absent more often than present. It may be represented by flint, iron ore, or impure shale. In the vicinity of Zaleski, the deposits, either flint or iron ore, are thin and local, but south of Raccoon Creek in Section 24 the flint is better developed and more persistent. It was quarried by the aborigines along the stream beds, carried to the ridges, and there worked into implements for hunting and domestic use. Chipping grounds with much refuse are still evident in this locality. A measurement of the bed is given in the following record taken in central Section 33:

	Ft.	In.
Flint, dark brown to black.....	1	0
Flint, dark gray.....	} <i>Zaleski</i>	6
Flint, shaly, dark.....		7
Coal, <i>Ogan</i>		8
Clay, siliceous.....	1	0

The position of the Zaleski member is about 30 feet above the Brookville coal and 20 feet below the Clarion member. The stratum is above drainage but poorly developed along Elk Fork near Vinton Furnace in Section 31.

The area in which the Zaleski member is due above drainage in Vinton Township is confined to the valley of Pierce Run from Oreton to Radcliff, but no deposits of flint or even iron ore were observed, although the overlying Winters coal is steady and well developed. This member likewise fails in parts of Clinton Township. The deposits are not only isolated but change in character from hard flint to siliceous shale. It is best represented near Hamden Furnace. Near Dundas the horizon is locally marked by iron ore or shaly flint. The stratigraphic relations are shown in the following record, taken along the road in northwestern Section 16:

	Ft.	In.
Sandstone, massive.....	31	8
Coal blossom, <i>Winters</i>	1	0
Clay, impure.....	2	0
Flint, dark gray, shaly, <i>Zaleski</i>		4
Coal, rotten, <i>Ogan</i>		8
Clay, dark, plastic.....	4	4
Sandstone, soft.....	8	0

	Ft.	In.
Shale, dark.....	4	6
Shale, gray.....	10	6
Covered, <i>Brookville</i> coal in interval.....	22	0
Sandstone, shaly.....	18	0
Sandstone and sandy shale.....	8	0
Ore, siliceous, <i>Upper Mercer</i>		3

In sections 22 and 23 the flint thickens locally to as much as 2 feet or more. It is usually calcareous in composition and shaly in character. The member is closely overlain by the Winters coal which is mined in a small way for domestic fuel. The following measurements, taken in central Section 23, are approximately representative:

	Ft.	In.
Coal blossom, <i>Clarion</i>	2	0
Clay and covered.....	11	0
Sandstone, soft, argillaceous.....	10	0
Clay shale, gray.....		5
Coal, good.....	1	6
Clay, impure.....	} <i>Winters</i>	3
Coal, somewhat bony.....		1
Shale and bone coal.....		7
Clay and covered.....	1	6
Flint, dark, calcareous, <i>Zaleski</i>	1	10

The Zaleski member, represented by either flint or iron ore, is locally present also in western Milton, eastern Washington, eastern Coal, and eastern Lick townships, Jackson County. The associated Ogan and Winters coals are very uncertain and frequently wanting.

Economic value

The flint of the Zaleski member was of far more value to the aborigines than it has been to the white man as it was extensively used by these prehistoric people living along the Scioto Valley and in other parts of southern Ohio. A goodly portion of the dark-colored flint implements used by them was from this source. The bed was quarried to some extent throughout the entire area of outcrop in Vinton and Jackson counties. From the abundance and the wide distribution of implements from Zaleski flint, the native people evidently regarded these deposits next in value to the great bed of Vanport flint on Flint Ridge in Licking and Muskingum counties. The flint used was obtained not so much by quarrying as simply gathering large blocks exposed along hillsides and stream beds. The quantity of such material is large. The Zaleski flint chipped easily and was fashioned into arrows, spears, knives, drills, scrapers, and skinners, many showing a high degree of workmanship.

The Zaleski member is of little value at present as neither the flint nor the iron ore is employed for useful purposes. The iron ore was formerly mined in a small way at a few places near Dundas and near Hamden for smelting in the charcoal furnaces. It was worked only along the outcrop where the ore is a soft limonite. The deposits are local and variable, and from 2 inches to 1 foot thick. The quality of the ore is generally poor as it is very siliceous in character.

WINTERS COAL AND CLAY

Stratigraphy and extent

The Winters coal, named for deposits on the Winters farm located about one mile southwest of McArthur, is another member with small areal extent as it has been recognized with certainty only in southern Vinton and northern Jackson counties. The total area of this basin is approximately 130 square miles in Vinton County and 50 square miles in Jackson. The position of the Winters coal is just above the Zaleski flint and about midway in the interval between the more important Brookville and Clarion coals. The field is not only small but within it the bed is unsteady and variable. During the period the regional deposition in the waters of the sea appears to have been shale and sandstone. In this small area, however, swamp conditions were established giving rise to the formation of clay and coal, but in it the local diversity in depth and circulation of water, infiltration of sediments, abundance and nature of flora, and other factors was such that the Winters beds were deposited with wide variation in both thickness and character.

The Winters coal expands erratically from a mere soot streak to more than 4 feet. In the main field the average thickness of the bed from more than forty measurements is 2 feet 3 inches. In character it changes from a rather pure fuel to shaly coal and on to carbonaceous shale. Further, in places the stratum is free from partings whereas elsewhere it is much divided by such layers. The clay associated with the Winters coal likewise lacks uniformity in thickness and composition. The variation in thickness is from 6 inches to 10 feet with an average of about 3 feet 6 inches. In general this clay belongs to the siliceous, plastic type common to the coal formations. It bears sufficient basic impurities to reduce it to low refractory rank. Impure ganister and siliceous flint clay are locally present in irregular bodies on the horizon. The members are best developed near McArthur, Zaleski, Hamden, and Oretton.

Brown Township.—Throughout western Brown Township the only patches of Winters coal observed were in sections 19, 25, 26, 31, and 32. These deposits are not only small but the coal is thin and impure.

Swan Township.—The Winters member as a well-defined unit is absent in all of Swan Township except along Raccoon Creek in the southeastern portion where it appears in isolated areas. The stratum is too impoverished to be of economic importance.

Jackson Township.—In Jackson Township such deposits are confined to the southeastern part where they occur only on the high ridges and knobs along the main water divides between Salt Creek and Raccoon Creek. The elevation of the bed is 1,030 feet at the Shively School in Section 23 and 995 feet near the Curry School in Section 36. Both the Winters coal and the Zaleski flint appear to be persistent. Outcrop exposures indicate that the coal is 6 inches to 2 feet thick but its position near the ridge summits is not favorable for mining.

Richland Township.—The area in which the Winters coal is locally present in Richland Township includes that along and that east of the main divide extending from Pawpaw School in Section 1 to near Richland Furnace in Section 3, south. In this field the stratum is not only unsteady but in few places well developed or of sufficient thickness for mining even in a small way.

Outcrop exposures indicate that in Section 1 the Winters coal expands irregularly from a few inches to about 2 feet. In the southeastern part of Section 2 it lies near the ridge summit about 990 feet above tide. In a prospect mine on the property of John Reynolds, Jr. in southern Section 13, the deposit has the thickness and structure shown below:

	Ft.	In.
Shale, gray.		
Shale, with thin coal bands		6
Coal, with thin shale partings.....	} <i>Winters</i> , altitude 953 feet	10
Coal, fair quality		8

The Winters coal at this place is 21 feet below the Clarion coal and 27 feet below the Vanport limestone. In the southeastern part of the township the member is everywhere thin and in places wanting. Its position on Jackman Ridge in Section 28 is about 1,030 feet and in central Section 35 nearly 930 feet.

Elk Township.—The maximum development of the Winters coal in Ohio is found in Elk Township but even in this area it is far from steady and is variable in both thickness and character. The stratum has been mined at many places for local needs and at a few places for railroad shipment. The thicker deposits are largely exhausted.

In sections 1, 2, 3, 4, 5, and 6, the Winters coal is absent except in local patches where it is thin and impure. The member is more prominent in sections 7 and 8 and has been mined in a small way just west of Elk Fork in central Section 9. In southeastern Section 11, the member has the thickness and structure given below:

	Ft.	In.
Shale, gray.....	15	0
Coal, bony.....	} <i>Winters</i>	7
Shale, black.....		7
Coal, good.....		2
Clay, impure.....		3
Shale, black.....		5
Coal, good.....		7
Clay shale.....	2	4
Coal, shaly.....	}	1
Clay, plastic.....		7
Flint, black to gray, <i>Zaleski</i>	2	11

The deposits are likewise thin or shaly in sections 12 and 13 but show improvement in Section 14 where they expand locally to 2 feet or more and where the fuel is of fair quality. In a mine on the George Wrightsel farm in central Section 15, the following measurements were secured:

	Ft.	In.
Shale, dark.....	2	0
Shale, bony, fossiliferous.....		4
Shale, dark.....		1½
Coal, 8 to 10 inches.....	} <i>Winters</i> , altitude 840 feet	8
Clay, siliceous.....		2½
Coal, irregular.....		8
Shale, carbonaceous.....		¼
Coal, irregular.....		1½
Shale, carbonaceous.....		¼
Coal, 1 foot to 1 foot 8 inches.....	1	2
Clay, plastic, gray.....	2	0

In this mine the coal benches are very irregular in thickness and the partings change rapidly as they are lenticular in character. The bed lies only a few feet above the *Zaleski* flint, 22 feet above the *Brookville* coal, and 18 feet below the *Clarion* member. The *Winters* coal was formerly mined in southwestern Section 16 and in southeastern Section 17. The thickness is reported to vary from 2 to 5 feet. Near by on the property of Benjamin Dillon, the following record was secured:

	Ft.	In.
Ore and flint, <i>Vanport</i>	1	0
Shale and covered.....	33	7
Sandstone, soft.....	2	0
Shale, argillaceous.....	1	0
Shale, dark, fissile.....		8
Coal.....		½
Shale, dark, bony.....		1
Shale, dark, argillaceous.....		5
Coal, good.....	} <i>Winters</i> , altitude 900 feet	8
Clay, shale, dark.....		3½
Coal, good.....		5

	Ft.	In.
Shale, dark.....		1½
Coal, good.....		8
Shale, bony, with pyrite.....		¼
Coal, good.....	2	0
Clay, impure.		

Winters, altitude
900 feet

The bed is mined in a small way both by stripping and by drifting. The best deposits in this locality are now largely exhausted, but to the west in sections 18 and 19, the member is regularly present but has less thickness. East of McArthur in Section 21, the Winters coal has also been mined for many years to supply the local trade. At the mine of George Thompson the following record was taken at the head of the entry:

	Ft.	In.
Sandstone, massive.		
Coal.....		9
Clay shale.....		4
Coal.....		8
Clay shale.....		1
Coal.....	1	8
Clay, plastic.....	2	0

Winters, altitude 860 feet

The coal is hard, bright, and clean. Its position is about 4 feet above the Zaleski flint and 35 feet above the Brookville or Newland coal which was also mined in this locality. In sections 22, 23, and 24, the deposits are in general not so thick and are more variable in character. The Winters coal was formerly mined for shipment by John West on the property of William Elliott in east central Section 26. A sample was cut for testing. (See analysis, page 195.) The measurements secured are given below:

	Ft.	In.
Shale, dark.....	6	0
Coal, bony, sampled.....		3½
Coal, good, with irregular pyrite band		
8 inches from top, sampled.....	1	0
Shale, rejected.....		4
Coal, sampled.....		4½
Shale, rejected.....		1¾
Coal, sampled.....	1	5
Clay, very siliceous.....	1	1
Flint, black, <i>Zaleski</i>	1	1
Shale, black.....		5
Coal, <i>Ogan</i>		9
Clay, plastic.....	2	0

Winters

In places in the mine the Zaleski flint and associated materials are so thin that the Ogan coal was worked along with the Winters. Much good fuel is yet available in this locality. At this place the Winters

coal lies 36 feet above the Brookville member. West of this at the mine of Allen Townsend, its position with reference to the Vanport limestone is shown. The strata exposed are as follows:

	Ft.	In.
Limestone, <i>Vanport</i>	6	0
Covered.....	39	8
Shale, dark.....	8	0
Ore, siliceous.....		4
Shale, dark gray.....		9
Coal.....		7
Clay, impure.....		5
Coal.....		6
Shale, carbonaceous.....		1
Coal.....	1	9
Clay, siliceous.		

Winters

At the mines of the McArthur Brick Company in southwestern Section 27, where it was formerly mined for local use, the Winters coal varies from 1 to 4 feet in thickness. As shown in the cut of the shale pit the stratum expands and contracts rather rapidly and erratically and varies not only by changes in the thickness of the separate coal benches but also by the addition or disappearance of other layers. The general stratigraphy of the Winters coal is also well defined at this place as is shown in the following section:

	Ft.	In.
Shale, siliceous.....	6	0
Shale, hard, gray.....		7
Coal.....	1	2
Shale.....		5½
Coal.....	1	6½
Shale.....		1
Coal.....	1	3
Clay, siliceous.....	2	9
Sandstone, argillaceous.....	8	0
Shale, gray.....	3	2
Shale, black, fissile.....	1	1
Coal.....		8
Shale and clay, irregular.....		4
Coal.....		8
Shale, bony.....		1
Coal.....	1	1
Clay, gray, plastic.....	7	6
Clay, dark, plastic.....	3	0
Shale, gray.....	22	0
Shale, gray, calcareous, very fossiliferous, <i>Putnam Hill</i>	2	6
Coal, <i>Brookville</i>	1	8
Clay, light, plastic.....	5	2
Shale, gray, argillaceous.....	8	8
Covered.....	33	9
Shale, dark.....	3	0
Shale, black, fissile.....		5
Coal, bony, <i>Upper Mercer</i>		2

Clarion

Winters

	Ft.	In.
Clay shale with irregular sandstone layers	1	0
Shale, gray, siliceous	2	4
Ore, kidney, <i>Lower Mercer</i>		3
Shale, gray, very siliceous	2	3
Shale, gray	3	6
Ore, irregular		2
Shale, dark blue, fossiliferous	1	3
Limestone, gray, fossiliferous		8
Shale, blue, fossiliferous		9
Limestone, hard, blue, fossiliferous		4

} *Lower Mercer*

In the above section the Zaleski flint and the Ogan coal, usually associated with the Winters member, are absent but they appear near by on the proper horizon. The type locality for the Winters coal is on the Winters farm in west central Section 28 where the bed was worked for many years. The mines were all abandoned when the region was visited in 1923-24. According to Orton, the member here¹ consists of two coal benches, each 2 feet thick, separated by shale, 1 to 6 inches thick. Near by on the farm of Miles E. Dawson in central Section 29, the following measurements were obtained in a drift mine:

	Ft.	In.
Coal, <i>Clarion</i> , reported thickness	4	0
Covered	24	6
Shale, gray	2	0
Shale, coaly		8
Coal	2	3
Shale		1½
Coal		4
Shale		1
Coal	2	0

} *Winters*

In this locality the Winters coal lies also about 27 feet above the Brookville coal and 92 feet above the Lower Mercer limestone. In sections 30 and 31, the member is usually present but variable in thickness and in character. In central Section 32, it is mined in a small way on the farm of Edgar Harper where the following measurements were taken in the main entry:

	Ft.	In.
Shale, gray, with ore nodules	10	0
Shale, dark		10
Coal, bony		5
Clay shale		1
Coal	1	2
Clay shale		1
Coal		11
Clay shale		1½
Coal	1	11
Shale, bony		2
Clay, impure		9
Flint, <i>Zaleski</i> .		

} *Winters, altitude*
910 feet

¹Geol. Survey Ohio, Vol. V, p. 1,000.

In west central Section 35 on the property of Reese Ankrum the Winters coal was formerly mined for shipment. The stratum varies from 2 feet 4 inches to 3 feet 6 inches in thickness and lies 23 feet below the Clarion coal which was also worked for the general trade.

Madison Township.—The Winters member appears above drainage in Madison Township only along Raccoon Creek, Elk Fork, and their tributaries in the western part. In general the deposits are thin and impure and have furnished but little fuel even for local needs.

In the vicinity of Zaleski in sections 30, 36, 35, and 29, the bed is wanting or thin and impure. In southwestern Section 33 on the George L. Ferris property, the Winters member is mined by drifting. A sample for analysis was taken at the head of the main entry. (For analysis see page 196.) The stratum at this place has the thickness and structure shown below:

	Ft.	In.
Sandstone, massive, lower surface irregular.....	5	0
Coal, bony, rejected.....	1	2
Shale, gray, rejected.....		3
Coal, good, sampled.....		0
Shale, soft, rejected.....		2
Coal, good, sampled.....		7½
Shale, rejected.....		½
Coal, good, sampled.....		8

Winters, altitude
755 feet

In this locality the Winters coal lies only a few feet above the Zaleski flint and 37 feet above the Brookville coal. Near Vinton Furnace in sections 31 and 25, the deposits are generally thin and much broken by shale partings.

Vinton Township.—The area of Winters coal above drainage in Vinton Township is small as the deposits are confined to the valley of Pierce Run from Oretown to Radcliff. The stratum is persistent but otherwise shows much variation, especially in its stratigraphic position, as in places it lies only a few feet below the Clarion coal whereas elsewhere it is separated from the higher member by 20 to 30 feet of shale and sandstone.

In south central Section 28, the Chicago-Oretown Company worked the Winters coal for the general market. Measurements obtained in the mines are given below:

	Ft.	In.
Limestone, <i>Vanport</i>	5	0
Shale, gray.....	16	0
Coal.....	1	4
Coal, bony.....	1	2
Clay, impure.....		5
Coal.....		9
Clay, impure.....		1
Coal.....		2

Clarion

	Ft.	In.
Sandstone and covered.....	15	0
Coal.....	1	6
Clay shale.....		$\frac{1}{2}$
Coal.....	1	$6\frac{1}{2}$
Coal, bony.....		2
Clay, impure.....	1	0
Coal.....		6
Clay, siliceous.....	2	0

The Winters coal is bright and hard and of fair quality, being much superior to the overlying Clarion. Locally in this area the overlying sandstone replaces a part of the stratum. This decrease by replacement is shown in the following record taken near the road forks in central Section 27:

	Ft.	In.
Sandstone, massive.....	15	0
Disconformity.....		
Coal.....		7
Coal, bony.....		1
Shale, carbonaceous.....		$\frac{1}{2}$
Coal.....	1	$6\frac{1}{2}$
Shale, coaly.....		3
Clay, plastic.....	3	0

At this place the bed varies from 2 to 3 feet in thickness. Near Radcliff the member is also generally thin and uncertain.

Clinton Township.—The Winters member, although rather widely distributed in Clinton Township, is most persistent and noteworthy in the central part where it has been mined in a desultory way for local needs. Owing to the patchy nature of the deposits, they differ in thickness, structure, and character from place to place. The associated Zaleski and Ogan members are only locally present. In this area the position of the Winters member is 12 to 30 feet below the Clarion coal with an average interval of separation of about 20 feet.

In the northwestern part of the township the Winters member is poorly developed, the thickest deposits observed measuring only about 1 foot. Near drainage level in west central Section 10, the bed has been mined in a small way both by stripping and drifting. The thickness reported is 1 foot 8 inches. In a prospect opening at the A. R. Walker mine in northeastern Section 11, the following measurements were secured:

	Ft.	In.
Sandstone, soft.....	10	0
Coal, good.....		6
Shale, dark.....		2
Coal, bony.....		2
Coal, good.....		6

	Ft.	In.
Shale, carbonaceous.....	} <i>Winters</i>	$\frac{1}{2}$
Coal, good.....		8
Shale, dark, carbonaceous.....		7
Coal, fair.....		3

At this place the position of the Winters coal is 30 feet below the Clarion coal and 70 feet below the Lower Kittanning member. Outcrop exposures at an elevation of 820 feet indicate that the bed is generally thin in southwestern Section 13. The deposits are of little value also in sections 14, 15, and 16, where locally the member is underlain by the Zaleski flint and its associated Ogan coal. In Section 23 the Winters coal so improves in thickness and in quality that it is mined for local fuel. At a drift mine in the west central part, the following record was obtained:

	Ft.	In.
Limestone, <i>Vanport</i> , poorly exposed.....	2	0
Covered.....	4	0
Coal blossom, <i>Clarion</i>	3	0
Clay, light, plastic.....	4	0
Sandstone, light, clay-bonded.....	16	0
Shale, siliceous.....	5	0
Shale, dark.....		7
Coal, very bony.....		8
Coal, good.....	} <i>Winters</i> , altitude 780 feet	10
Clay, impure.....		3
Coal, good.....		4

Mining conditions are fair as the overlying shale is moderately strong and as the underlying clay is hard and siliceous. For domestic use the Winters coal is considered much superior to the Clarion. On the Tarr farm in central Section 23, the Winters member has also been mined by drifting. At this place the thickness of the lower bench of coal is 1 foot 1 inch, the clay parting 3 inches, and the upper bench of coal 1 foot 6 inches. It lies about 2 feet above the Zaleski flint which here has a thickness of 1 foot 10 inches. At a small mine in the southwestern corner of Section 27, a measurement of this stratum was secured. The record follows:

	Ft.	In.
Sandstone, shaly.....	3	0
Sandstone, massive.....	1	3
Shale, dark.....	1	0
Coal, good.....	} <i>Winters</i>	1
Clay, impure.....		2
Coal, good.....		8
Coal, bony.....		2
Clay, impure.....		$3\frac{1}{2}$
Bone coal.....		$3\frac{1}{2}$

South of Hamden Furnace in Section 28, the Winters coal was formerly mined at a few places. The bed is reported to vary from 1 foot to 3 feet 6 inches in thickness.

Economic value

As a fuel asset to Vinton County the Winters coal ranks fourth, being surpassed by the Middle Kittanning, Clarion, and Brookville members. This coal has been worked in but few places for shipment but it has been mined for many years over a rather wide area for a part of the local domestic supply. As a whole the field is still far from exhaustion. It has been worked most largely in Elk Township and to a less extent in western Madison, western Vinton, and eastern Clinton.

The Winters coal is of the ordinary bituminous type, differing little in appearance from other coals in the Allegheny formation of Ohio. It burns freely owing to the high content of volatile matter and has a fairly high ash content and a moderately low heating value. The general quality of the Winters coal is shown by the following analyses:

The member was sampled by W. Stout in 1922 at the mine of John West on the William Elliott property in Section 26, Elk Township. The sample was taken at the head of the entry, well under deep cover, and is representative:

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	64.04	68.63	Moisture.....	6.69	.00
Hydrogen.....	4.98	4.54	Volatile matter.....	35.56	38.11
Oxygen.....	14.63	9.30	Fixed carbon.....	43.95	47.10
Nitrogen.....	1.21	1.30	Ash.....	13.80	14.79
Sulphur.....	1.34	1.44			
Ash.....	13.80	14.79			
	100.00	100.00		100.00	100.00

		As received	Moisture free
Heating value.....	{ Calories	6,251	6,699
	{ B. t. u.	11,251	12,058

Fusion of ash, incipient above 2,650° F.

A sample was also taken in a drift mine on the land of George L. Ferris, Section 32, Madison Township. It was cut by W. Stout in 1922. The coal was bright and solid but the mine somewhat moist.

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	68.54	72.96	Moisture.....	6.06	.00
Hydrogen.....	5.12	4.74	Volatile matter.....	38.74	41.24
Oxygen.....	14.46	9.66	Fixed carbon.....	46.38	49.37
Nitrogen.....	1.25	1.33	Ash.....	8.82	9.39
Sulphur.....	1.81	1.92			
Ash.....	8.82	9.39		100.00	100.00
	100.00	100.00			

		As received	Moisture free
Heating value....	{Calories	6,751	7,186
	{B. t. u.	12,151	12,935
Fusion of ash....	{Incipient 2,560° F.		
	{Complete 2,640° F.		

The Winters coal is best suited for general heating and steam making purposes. It is satisfactory also for burning the more common kinds of ceramic products as it burns freely until consumed and produces a long flame which imparts color and finish to the ware. Locally it has a good reputation for household use. The ash, although rather large in amount, is clay-like in character and clinkers only at high temperatures. Some soot is produced in burning but the quantity is not enough to be troublesome. On the whole, the Winters coal has sufficient merit to serve most of the uses to which locally it is applied.

The general mining conditions of the Winters coal are about on a par with those of other beds in the Allegheny formation of this region. The roof in most of the field is usually a tough gray shale or a massive sandstone, both solid and strong, but in a few places near McArthur the bed is overlain by a tender shale which crumbles on exposure to the air. Thin layers of "draw slate" are also locally present in eastern Elk and central Clinton townships. The floor of the coal is a siliceous clay which makes fair footings for posts and tracks. On account of the clay partings in the deposits the coal as mined is somewhat dirty and on exposure to the weather it is discolored by whitewashing. Bone bands and pyrite lenses are not common impurities. This coal is too tender to withstand severe shooting and handling without considerable loss in "fines." In the thicker deposits throughout most of the field, however, the conditions for mining the Winters coal at a moderate cost are not prohibitive. Quality, alone, excludes it from the best markets. The chief value of the Winters coal in Vinton County is not to supply fuel for the general trade but to furnish what is needed for local purposes. Thus applied the maximum benefits may be obtained from an asset otherwise yielding little revenue to the region.

CLARION SANDSTONE

Stratigraphy, extent, and value

The Clarion sandstone with wide areal extent and massive development in parts of southern Ohio is poorly represented in most of Vinton County. Like most sandstones in the coal formations of Ohio, its position is somewhat indefinite. The thick deposits fill most of the space between Brookville coal and Clarion clay but the thin deposits are confined more to the upper part of this interval. The lower surface of such deposits is far more irregular than the upper. In Vinton County, where the small basin bearing the Ogan coal, Zaleski flint, and the Winters coal appears, the position of the Clarion sandstone is between the Winters coal and the Clarion clay. Such deposits, however, are local and variable.

In Swan Township the Clarion sandstone is most conspicuous in the northeastern part where it varies in thickness from 5 to 25 feet. Thin lenses of such material are rather widely distributed in Elk Township and appear with some regularity in southwestern Madison. In Vinton Township the member is very persistent in the small area of outcrop along Pierce Run from Oretton to Radcliff, where it is the chief material filling the interval between the Winters coal and the Clarion clay. The thickness of the stratum varies from 1 to 27 feet. Similar conditions are found in eastern and central Clinton Township.

The Clarion is an open, loosely cemented sandstone, rather fine in texture and micaceous in character. It varies in color from light gray in unweathered material to pale buff on exposed surfaces. The bonding components are clay matter and iron compounds. This sandstone decomposes readily on weathering, making it unfit for building purposes, and it is far too impure and too fine in grain for glass making or concrete work. The only probable use is for molding sand for small castings.

CLARION CLAY

Stratigraphy and extent

The Clarion is by far the most valuable clay bed in Vinton County, surpassing any other in quality, quantity, and availability. For a coal formation clay of the plastic type the material present here is scarcely surpassed elsewhere in the whole Appalachian field. The conditions for utilization are further enhanced by the fact that the best deposits are present in areas in which the coal beds are also well developed, clay and coal thus being directly available. Besides these advantages, the railroads are situated conveniently for plant location and afford ship-

ment to distant markets. This great clay asset has as yet not been touched but in the future it should yield a large return to the region.

The Clarion clay is present in western Brown, Swan, southeastern Jackson, eastern Richland, Elk, western Madison, western Vinton, western Wilkesville, and Clinton townships, but the deposits of most value are confined to Brown, Elk, Vinton, and Clinton townships. The quantity of clay directly available by mining is sufficiently large to supply many plants for generations. The Clarion clay is directly associated with the Clarion coal, lying just below this well-known stratum. The thickness of the member varies from 2 to 15 feet with an average from more than 80 measurements slightly in excess of 6 feet. The horizon bears both plastic and flint clay, the plastic being the chief and usually the only kind present.

Brown Township.—The Clarion clay is a persistent bed throughout Brown Township. It is present above drainage in the western and the central parts in an area of approximately 25 square miles. Near New Plymouth the member lies well above the valleys at an elevation of 860 to 880 feet. The Clarion clay is exposed at many places along Twomile Run from its mouth to Section 24 where it passes below cover. In the southwestern corner of the township, or in Section 31, the elevation of the stratum is about 835 feet, thence it dips eastward along Raccoon Creek, finally disappearing below the flood plains in the central part of Section 7. On Sandy Run the member lies just below or not far above drainage from the mouth of the stream to the southern part of Section 11. Local exposures are also present along the larger western tributaries and along Little Sandy Run for a distance of more than 2 miles. The deposits most available to the railroads are along Raccoon Creek from Zaleski to Moonville, along Sandy Run from Hope Station to Hope Furnace, and along the ridges southeast of New Plymouth.

In Brown Township the Clarion clay is seldom less than 5 feet thick and in places it expands to more than 12 feet but the average measurement is about 7 feet. In the main, the member is composed entirely of plastic clay with occasional thin lenses of flinty material. In the stratum the distinct types of plastic clay show great uniformity laterally but considerable variation vertically. A layer from 6 to 12 inches thick immediately underlying the Clarion coal is dark in color and somewhat rough in texture but its exclusion is not necessary except for possibly a few high-grade products. This dark clay is underlain by 2 to 4 feet of light-colored clay of exceptional purity, which is fine grained, very plastic, and only slightly siliceous. The lower layer of the clay bed proper varies from 2 to 4 feet in thickness and the character of its material is much the same as that above except that it is high in siliceous matter. The Clarion clay is underlain by a light-colored, clay-bonded sandstone, which may be utilized if more silica is desired in the batch.

Along the ridges in sections 36 and 30, the Clarion clay outcrops at an elevation of about 860 feet but it was not found sufficiently well exposed for definite measurements. Just north of this, however, in the central part of Section 25, Starr Township, Hocking County, the following record was secured:

	Ft.	In.
Shale, black, fissile.....	2	0
Coal, <i>Clarion</i>		9
Clay, dark, rough.....		10
Clay, light, plastic.....	2	8
Clay, light to dark, flinty.....	2	0
Clay, plastic, dark.....	1	2
Clay and covered.....	1	4
Sandstone, argillaceous.....	2	0

The clay in this deposit is all of excellent quality, except that just below the Clarion coal, which is somewhat impure. Along Raccoon Creek in Section 35 and along Twomile Run in sections 29 and 23, it is not so well developed, averaging only about 5 feet in thickness, but is up to the standard in quality. The stratigraphic relations of the Clarion clay to beds higher in the Allegheny formation are shown in the following composite record taken at the road forks in northeastern Section 23:

	Ft.	In.
Sandstone, soft, massive.....	75	0
Coal, bony.....		4
Clay with thin coal bands.....		3
Coal, good.....	2	8
Clay shale.....		1
Coal, good.....	1	$\frac{1}{2}$
Covered.....	25	8
Coal, weathered, <i>Lower Kittanning</i>		6
Clay, plastic, light, lower part siliceous.....	9	6
Sandstone, massive, soft.....	33	0
Shale, gray, siliceous.....	7	4
Ore, irregular.....		1
Shale, dark.....		10
Coal, shaly, <i>Scrubgrass</i>		8
Shale, dark, part covered.....	3	1
Shale, black, fissile.....	3	11
Shale, black, fissile, blocky.....	1	3
Coal, <i>Clarion</i>		10
Clay, light, plastic.....	2	6
Clay, light, plastic, siliceous.....	2	6
Sandstone and covered.....	21	0

Locally in this vicinity the Clarion clay thickens to as much as 7 feet. Along Raccoon Creek in sections 34, 33, and 32, the deposits, although poorly exposed, appear to be equally well developed. In Big Sand Woods near the head of Little Sandy Run, the member out-

crops in the stream bed at an elevation of 830 feet. The following strata were there uncovered:

	Ft.	In.
Shale, gray.....	3	0
Coal, bony, <i>Scrubgrass</i>		7
Shale, black.....	3	1
Coal, good, <i>Clarion</i>	1	4
Clay, dark, impure.....		4
Clay, light, plastic, lower part some- what siliceous.....	5	8
Sandstone, light, argillaceous.....		
	1	0

Elsewhere along this stream the Clarion clay is very constant in extent, thickness, and character. Exposures are too few and poor to determine the exact nature of the deposits in Bungle Hollow in Section 26; along Raccoon Creek, in Section 25; and in Strong Hollow in Section 31. At the Brewer Cut of the Baltimore and Ohio Southwestern Railroad in northern Section 19, this clay has excellent development and purity. A record of the rocks seen at this place is given below:

	Ft.	In.
Shale, gray.....	10	0
Coal, bony, <i>Scrubgrass</i>	1	3
Shale, dark, fissile.....	6	0
Coal, good.....	1	8
Shale, argillaceous.....		1
Coal, good.....		7
Clay, dark, somewhat flinty.....	1	0
Clay, light, very pure.....	2	9
Clay, light, siliceous.....	2	6
Shale, siliceous, argillaceous.....	3	4
Sandstone, gray, shaly.....	1	6
Shale, gray.....	1	0
Ore, siliceous, in two layers.....		8
Shale, gray.....	3	10
Sandstone, shaly.....		10
Shale, dark, carbonaceous.....		10
Ore, irregular.....		1
Coal, bony, <i>Winters</i>		7
Clay, siliceous.....	6	0
Shale, gray, siliceous.....	10	0
Track level.		

In the deep hollow in the southern part of this section, more than 5 feet of Clarion clay was exposed in the stream bed at an elevation of 740 feet. The member appears also just above drainage level on the Ira Penny farm in east central Section 19 where the deposit shows the following specific features:

	Ft.	In.
Shale, gray.....	5	0
Coal, bony, <i>Scrubgrass</i>	1	4
Shale, black, fissile.....	6	10

	Ft.	In.
Coal, <i>Clarion</i>	1	5
Clay, dark.....	1	2
Clay, light, plastic, excellent.....	3	6
Clay, bluish-gray, siliceous.....	1	8
} <i>Clarion</i>		
Sandstone, light, clay-bonded.....		1
Coal, shaly.....		$\frac{1}{2}$
Clay, dark, plastic.....		4 $\frac{1}{2}$
Coal, shaly.....		$\frac{1}{2}$
Clay, light, plastic.....		6
Coal, shaly.....		1
Clay, plastic, not well exposed.....	1	0
Covered.		

On the farm of Jesse White just south of Hope Station, a sample of *Clarion* clay was taken for testing by the writer assisted by Mr. Miles Ogan, in November, 1923. It was secured by channeling the bed where vertically faced in a deep ravine. (See tests, page 211.) The measurements of the various strata here laid bare are given below:

	Ft.	In.
Coal, rotten, <i>Clarion</i>	1	0
Clay, plastic, dark, impure, sampled.....		4
Clay, plastic, dark, good, sampled.....		8
Clay, plastic, light, very pure, sampled.....	3	6
Clay, plastic, light, slightly siliceous, sampled...	2	6
Clay, plastic, dark gray, pure, sampled.....	1	4
Clay, plastic, light, very siliceous, rejected.....		8
} <i>Clarion</i>		
Sandstone, light, clay-bonded.....	2	0

At other exposures in this locality on the Betz and Dunn properties, the member shows equal thickness and purity. On the farm of Timothy Clifford, located south of Raccoon Creek and about one-half mile east of Hope Station, this clay thins somewhat but retains its high quality. The section secured on the ridge south of the house follows:

	Ft.	In.
Coal, <i>Clarion</i>	1	1
Clay, plastic, dark.....		8
Clay, plastic, light, very pure.....	3	10
Clay, plastic, light, siliceous.....	1	8
} <i>Clarion</i>		
Sandstone, light, very argillaceous.....	3	8

Near the mouth of Big Sandy Run, the *Clarion* member is conspicuous by the heavy outcrop of plastic clay at an elevation of about 740 feet. The bed has been prospected on the Marvin Kasler property near Hope Station and is uncovered in a ravine west of the farm house. At the latter place the record which is given below was obtained.

	Ft.	In.
Shale, gray.....	2	0
Coal and bone shale, much weathered, <i>Scrubgrass</i>	1	0
Shale, black.....	4	0

	Ft.	In.
Coal, <i>Clarion</i>	1	5
Clay, dark, plastic.....	1	6
Clay, light, plastic, very pure.....	3	4
Clay, light, plastic, siliceous.....	3	8
Clay, light, very siliceous.....	2	0
Shale, argillaceous.....	2	0

The field of Clarion clay along Big Sandy Run and its tributaries in the central part of Brown Township is worthy of careful attention as the conditions are especially favorable for large ceramic operations. The clay has good continuity, thickness, uniformity, and purity. Mining conditions are excellent as the roof is everywhere a hard, fissile shale. Further, coal for manufacturing the clay into ware may be obtained from the Middle Kittanning member lying about 90 feet higher in the geological column. From the mouth of Big Sandy Run to Hope Furnace the bed lies not far above drainage. From Hope Furnace to the southern part of Section 11 it is at or just below the flood plain, and along the northern tributaries it is level-free to near their headwaters.

Along the road about one-half mile south of Hope Furnace, on land of George P. Drayer, the Clarion clay was sampled for testing in May, 1925, by W. Stout assisted by Messrs. Miles Ogan and George P. Drayer. The clay was faced to a depth of 3 feet or more and about 130 pounds of material then taken from top to bottom. (See tests, pages 212-3.) The sample is representative of the clay near the surface and should closely approximate that under deep cover. A section of the cut shows the following strata:

	Ft.	In.
Shale, dark.....	3	0
Coal, weathered, <i>Clarion</i>		10
Clay, dark, flinty, sampled.....		10
Clay, plastic, light, very pure, sampled.....	2	10
Clay, plastic, light, siliceous, sampled..	4	9
Sandstone, light, clay-bonded.....		6

At Hope Furnace the Clarion clay outcrops just above the flood plain but it is so buried that its character was not determined. A short distance northwest of the old stack it is uncovered in a gully north of the stream. The member at this place has the following thickness and structure:

	Ft.	In.
Shale, black.....	2	0
Coal, weathered, <i>Clarion</i>	1	2
Clay, dark, flinty.....	1	2
Clay, plastic, light, very pure.....	7	2
Clay, plastic, very siliceous.....	1	6

In this deposit the thickness of more than 7 feet of very pure clay is exceptional. The member, however, is above average development

along the first large tributary of Sandy Run west of Hope Furnace where it outcrops prominently in the stream bank on land of George P. Drayer. This deposit was sampled in the regular way for testing in May, 1925, by W. Stout assisted by Messrs. Miles Ogan and George P. Drayer. (See tests, page 214.) The clay and related strata are shown in the following section:

	Ft.	In.
Shale, black.....	6	0
Coal, <i>Clarion</i> , absent		
Clay, dark, flinty, sampled.....		10
Clay, light, plastic, very pure, sampled.....	4	6
Clay, light, plastic, somewhat siliceous, sampled.....	2	10
Sandstone, argillaceous, light.....		1
Clay, plastic, dark gray, somewhat siliceous....	1	7
Clay, plastic, light, very siliceous.....	1	4
Sandstone, light, argillaceous.....		4

At this place the clay sampled, 8 feet 2 inches" thick, is of fine quality and that in the entire bed, measuring 11 feet 2 inches, is very satisfactory for most purposes. The overlying *Clarion* coal appears to be absent only in a small area. On Big Sandy Run near the southern boundary of Section 11, on land of the Ohio Mineral Company, the *Clarion* members appear for a short distance just above water level. The clay where laid bare by stream erosion was sampled for testing in November, 1923, by the writer, assisted by Mr. Miles Ogan. Where channeled the clay was solid and the sample is therefore representative of the material under deep cover. (See tests, page 215.) A section of the rocks here is given below:

	Ft.	In.
Sandstone, shaly.....	3	0
Shale, gray.....	10	0
Coal, somewhat bony, <i>Scrubgrass</i>	1	1
Shale, dark, rather fissile.....	4	3
Shale, hard, bony, blocky.....	1	8
Coal, blocky, <i>Clarion</i>		6
Clay, dark, plastic, sampled.....		8
Clay, light, plastic, very pure, sampled.....	2	8
Clay, light, plastic, siliceous, sampled..	2	4
Clay, light, very siliceous.....	1	6

Along Raccoon Creek in the vicinity of Moonville, the *Clarion* clay is present above drainage at an elevation of nearly 720 feet. The deposits show both thickness and quality. In the hollow in west central Section 8 on land of the Ohio Oil Company, this clay is exposed in the bank of the stream and has the following measurements:

	Ft.	In.
Sandstone, massive.....	10	0
Shale, gray, siliceous.....	7	0
Shale, dark.....		9

	Ft.	In.
Coal, <i>Clarion</i>		11
Clay, dark, carbonaceous.....		4
Clay, light, plastic, pure.....	1 4 2 1	10
Clay, light, siliceous.....		4
Clay, light, very siliceous.....		2
Shale, blue.....		0

In the cut of the Baltimore and Ohio Southwestern Railroad in southwestern Section 8, this clay, exposed near track level, is more than 6 feet thick and of high purity. Along Raccoon Creek in central Section 7 just below the former site of Coe's Mill on land of A. E. Kennard, the bed outcrops about 10 feet above water level. The deposit was sampled for testing in May, 1925, by the writer assisted by Miles Ogan. (See tests, page 216.) The thicknesses of the various strata here exposed are given below:

	Ft.	In.
Shale, black, fissile.....	6	1
Coal, <i>Clarion</i>	1	1
Clay, dark, flinty, sampled.....	2 1 1 1 1	6
Clay, light, plastic, very pure, sampled.....		8
Clay, light, plastic, quite siliceous, sampled.....		4
Clay, light, plastic, siliceous, sampled.....		3
Clay, light, plastic, very siliceous, sampled.....		11
Sandstone, argillaceous.....		6
Shale and covered.....	7	0
Water level, Raccoon Creek.		

The field of *Clarion* clay in Brown Township is an asset of great value and should be developed. As shown by the various sections given, this clay is persistent in extent, steady in thickness, uniform in quality, and free from damaging impurities. Mining conditions are very good, as the bed is not only level free in most of the area but everywhere it has a tough shale roof and a hard, siliceous floor. Further, the thickness, averaging about 7 feet, is favorable for drift mining. The field also has a large reserve of Middle Kittanning coal directly available for factory needs.

Swan Township.—With the exception of a few isolated patches, the *Clarion* clay is confined to the eastern half of Swan Township where the bed lies near the summits of the main ridges. In general, the deposits are not especially well developed and the material is not above the average in quality. Locally the overlying coal has sufficient thickness for regular drift mining.

Near New Plymouth in the northeast corner of Section 1, the member outcrops about 900 feet above tide. Where exposed in the road the clay is more than 11 feet thick but most of it is very siliceous in character. Where observed in the vicinity of Mount Pleasant in

sections 3 and 4, the member is not conspicuous for either thickness or quality. Along the road in northeastern Section 11, the following rocks were exposed:

	Ft.	In.
Shale, dark	3	0
Coal blossom, <i>Scrubgrass</i>		6
Clay, impure	1	0
Shale, gray	4	0
Shale, black, somewhat fissile	7	0
Coal and partings, <i>Clarion</i>	3	0
Clay, light, plastic, <i>Clarion</i> , altitude 905 feet	4	0
Sandstone, clay-bonded	2	0

South of this in sections 13, 14, 23, 24, 25, 26, and 27, the *Clarion* coal has normal development but the underlying clay is much impoverished. The field as a whole is not attractive for ceramic operations.

Jackson Township.—In Jackson Township the *Clarion* clay is present only on the high knobs of the main ridges in Section 36. Its elevation is about 1,020 feet. The clay is of excellent quality, much resembling that in Brown Township. The thickness of the deposits varies from 6 to 8 feet.

Richland Township.—Only small patches of *Clarion* clay are present in Richland Township and these are confined to the high ridges in sections 1, 2, 13, and 24. The clay has fair thickness and purity.

Elk Township.—The *Clarion* clay is widely distributed in Elk Township, lying as it does near the summits of the high ridges in the western part and about midway up the hills in the eastern part. Its elevation is nearly 1,000 feet in Section 7, 960 feet in Section 30, 850 feet in Section 12, and 780 feet in Section 25. The deposits lack uniformity, varying greatly both in thickness and in character. The field of most promise is in the northeastern part of the township.

In sections 7, 8, and 18, the member is persistent and well developed. The deposits, however, are not extensive as they are confined to the knobs on the main ridges. In sections 10, 11, 14, and 15, this clay also shows fair development. In southwestern Section 12, the following measurements were obtained:

	Ft.	In.
Sandstone, massive	50	0
Coal blossom, <i>Clarion</i>	2	0
Clay, plastic, good, <i>Clarion</i>	6	0
Shale and covered	16	0
Coal blossom, <i>Winters</i>		6
Clay, shale, and covered	15	0
Shale, gray	17	0
Shale, gray, fossiliferous, <i>Putnam Hill</i>	3	6
Coal, weathered, <i>Brookville</i>	3	2
Clay, plastic	3	6

In the southeastern part of the township, the Clarion clay is thin and siliceous but the overlying coal attains normal development. The conditions are much the same in the vicinity of McArthur where the thickness of the clay varies from 1 to 6 feet but averages less than 4 feet. Locally it is so siliceous in character that it is more a clay-bonded sandstone than a true clay. The deposits improve both in thickness and in quality in sections 19, 20, 29, and 30, where the clay has high purity and is from 5 to 8 feet thick. As the covering is thin, the material may be mined by stripping.

Madison Township.—The Clarion member is present above drainage along Raccoon Creek, Wheelabout Creek, and Elk Fork in western Madison Township but appears only on Flat Run in the eastern part. The deposits, however, are inconstant as they show a wide variation, often in a short distance, in thickness, structure, and character. The clay with most merit occurs in the vicinity of Zaleski.

Along the abandoned road in southwestern Section 30, the Clarion clay is more than 6 feet thick and has high purity. It is overlain by the Clarion coal and this in turn by black, fissile shale. The elevation of the deposit is 780 feet. Along the road in central Section 35, the member has similar development and properties, as shown in the following record:

	Ft.	In.
Sandstone, massive, soft.....	50	0
Coal, bony, <i>Scrubgrass</i>		10
Shale, black.....	3	2
Coal, weathered.....	1	5
Shale.....	} <i>Clarion</i>	2½
Coal.....		7
Clay, plastic, dark.....	} <i>Clarion</i>	1 0
Clay, plastic, light, good.....		5 8
Clay shales and covered.....	4	6

The clay is of value also in parts of Section 29. At the mine of Ernest Eicher, it measures more than 5 feet in thickness. Along Wheelabout Creek the member is much impoverished as it is largely replaced by argillaceous sandstone. Moreover, the material present, from 1 to 4 feet thick, is very siliceous or even shaly in character. It improves but little in the vicinity of Prattsville and in Section 32. Locally along Elk Fork near Vinton Furnace, the Clarion clay again attains the properties necessary for ceramic work. The following rocks were exposed in north central Section 31:

	Ft.	In.
Shale, dark.....	1	4
Coal, weathered, <i>Clarion</i>	3	0
Clay, light, plastic, good, <i>Clarion</i> , altitude 740 feet.....	6	4
Covered.....	2	0
Sandstone, part shaly.....	17	0

At this place a part of the clay in the deposit is very pure, much resembling that in Brown Township. The member is present just above drainage along Elk Fork in sections 25 and 19, and on Flat Run in Section 13.

Knox Township.—The only locality in which the Clarion clay appears at the surface in Knox Township is along Raccoon Creek in the northern part of Section 12. Owing to the thick covering of alluvium, the bed was not exposed for investigation.

Vinton Township.—Although the Clarion member at no place lies far above drainage, yet it is rather widely exposed in Vinton Township. It is present along Pierce Run in sections 35, 34, 33, 27, 21, 20, and 19; along Raccoon Creek in sections 10, 9, 15, 14, 13, and 19; along Elk Fork in sections 36, 17, and 16; and along Alman Run in sections 28, 22, and 16. In general, the deposits are thin and impure. The most noteworthy features are local bodies of flint clay on the horizon.

On Elk Fork and along Alman Run in the central part of the township, no good clay, either flint or plastic, was found in association with the Clarion coal. The material present in exposures along Raccoon Creek from Arbaugh to Radcliff is also unpromising for ceramic use. In the vicinity of Oreton on Pierce Run, irregular bodies of siliceous, flint clay make up the basal portions of thick deposits lying below the Clarion coal. Stream or current action appears to have aided in the deposition of this material as it shows cross-bedding and selective separation. In it irregular lenses of flint clay and of argillaceous sandstone are inter-stratified in disorderly arrangement, thus producing great local variation. Either of these materials may predominate in such deposits but in general the clay is more abundant. The clay is a hard flint, gradating from quite pure to very siliceous. It is light gray, breaks with a true conchoidal fracture, and disintegrates into angular fragments on exposure to the weather. The plasticity is low. The following section shows the relations observed at the mines of the New York Coal Co. at Oreton:

	Ft.	In.
Limestone, <i>Vanport</i>	8	0
Shale, gray.....	10	0
Coal.....	1	2
Clay, with thin coal bands.....	1	8
Coal.....		0
Clay with pyrite.....		1
Coal.....		2
Clay and covered.....	8	0
Clay, flint, upper part mixed with sandstone, sampled.....	4	0
Shale, argillaceous, light.....	4	0

¹Owing to poor exposures and to irregularity in the deposition of the various Allegheny members in this locality, this flint clay was formerly described as Winters. (See Geological Survey of Ohio, Bull. 26, Coal Formation Clays of Ohio, pages 246-248.) It is now considered only a local variation of the Clarion member.

At this place a sample of the flint clay was taken for testing. (See tests, page 218.) The deposits are not extensive but have good thickness. Between Oretton and Radcliff the Clarion member appears to be represented by only a thin bed of siliceous, plastic clay, but near Campbell Tunnel, south of Radcliff, it again shows expansion and improvement. Near the mouth of the small western tributary of Raccoon Creek in central Section 19, the Clarion clay was well exposed in the stream bank on property of the Thompson Coal Co. The deposit here consists of 6 feet 6 inches of flint clay, overlain by 2 feet 6 inches of plastic material, and this in turn by the Clarion coal. The flint clay contains irregular lenses and masses of argillaceous sandstone, thus making it as a whole quite siliceous. Under deep cover in the mine near by on the same property, a sample was taken for testing. (See tests, page 219.) The section is given below:

	Ft.	In.
Shale, black.....	2	0
Coal.....	1	4
Clay with thin coal bands.....		7
Coal.....	1	1
Clay with pyrite.....		1
Coal.....	1	1
Clay, impure.....		6
Coal.....		5½
Clay, plastic, light to dark, sampled...	1	6
Clay, flint, siliceous, sampled.....	4	6
Clay, not sampled on account of water.		

On the farm of John Riley in northeastern Section 25, the Clarion member is exposed at several places along the south bank of the stream. It is made up of both flint and plastic clay, the flint variety occurring as irregular masses in the basal portion of the plastic. The flint clay is of the usual siliceous type but the plastic material is exceptionally pure. A section of one exposure follows:

	Ft.	In.
Shale, black, fissile.....	3	0
Coal.....	1	5
Clay, impure.....		6½
Coal.....	1	3
Shale.....		1½
Coal.....	1	2
Coal, bony.....		3
Clay, plastic, light to dark.....	4	0
Clay, flint, with irregular sandstone masses, replaced near by by plastic clay of high purity..	7	6
Clay, plastic, light.....	1	0
Stream bed.		

The Clarion member probably retains good development and properties to the west under the main ridges as it outcrops with such

characteristics at Lincoln Furnace in Jackson County. The field in southwestern Vinton Township thus appears to contain sufficient clay to support ceramic plants and also the necessary fuel to supply their needs. Other conditions favorable for successful operation, such as shipping facilities, labor, and water, are likewise satisfactory.

Wilkesville Township.—In Wilkesville Township the Clarion clay is above drainage along Raccoon Creek from Hawk to central Section 20 and along the lower courses of the larger western tributaries, Rockcamp, Indiancamp, and Karr runs. Throughout most of this area the bed outcrops so near the level of the flood plain that few exposures were found. These, however, indicate that some clay of value is present in the field. The overlying coal has good continuity and development.

Near Hawk in central Section 24, the following strata appear in the cut of the Hocking Valley Railway:

	Ft.	In
Sandstone, massive.....	30	0
Shale, bony.....		11
Coal.....	1	5
Clay, impure.....		7
Coal.....	1	2½
Clay, with pyrite.....		1½
Coal.....	1	2
Clay, hard.....		2
Coal, bony.....		2
Clay, plastic, light to dark.....	1	6
Clay, flint, siliceous, irregular.....	6	6
Clay, plastic, dark, siliceous.....		4
Clay, plastic, light.....	2	0
Track level.		

The flint clay is light gray in color and fine in texture. Within the stratum are found irregular lenses of very siliceous clay and argillaceous sandstone which, on the whole, constitute but a small part of the mass and which, if objectionable, may be removed in mining. More than 6 feet of flint clay is present on this horizon in south central Section 30. Near Clarion and Minerton the exposures were too poor to determine definitely the thickness and character of the Clarion clay.

Clinton Township.—Although widely distributed in Clinton Township, the Clarion clay only locally attains sufficient merit to be attractive to the ceramic worker. It is at its best in the southern part of the area where some deposits have excellent thickness and purity. In general, plastic clay alone is present on the horizon. At the Puritan plant of the McArthur Brick Company, this clay was formerly used for refractory products and at present it is employed for the manufacture of high grade face brick. The associated Clarion coal is normal in development throughout most of the field.

Near Dundas the Clarion clay, present at an elevation of approximately 860 feet, is generally thin and impure. In east central Section 14, it measures nearly 6 feet in thickness. The quality is fair. It improves in value in sections 22, 23, 26, and 27, where it lies not far above the valley floors. In the pit of the McArthur Brick Company in northeastern Section 28, the following measurements were secured:

	Ft.	In.
Limestone, <i>Vanport</i>	10	0
Shale, black, fissile.....	1	6
Coal.....	1	9
Shale with bone coal.....		8
Coal.....		4
Shale with pyrite.....		1½
Coal.....		11
Clay, dark, plastic, sampled.....	1	6
Clay, light, plastic, excellent, sampled.....	3	6
Clay, light, siliceous, sampled.....	4	0

At this place a sample of Clarion clay was taken for testing. (See tests, page 220.) It was cut through the entire 9 feet and is representative of the material in this locality. The bed is free from apparent impurities and is uniform in structure. It is mined both by stripping and by drifting.

Economic value

The Clarion clay, although it has been little worked in Vinton County, is by far the most important ceramic asset within the area. Such a base supply is adequate for a wide and extensive industry. The fields are not only large and accessible but are especially well located for plant operation as fuel, labor, and water are at hand. Further, nearby and distant markets are easily reached by the various railroads operating within or adjacent to the fields.

In general, the Clarion clay in most of the fields is plastic in kind and high in quality. It is very free from damaging impurities such as ore concretions, pyrite, gypsum, and calcareous nodules. Fine quartz sand and mica scales are present most commonly in the basal portion of the deposits but not in sufficient quantities to impair the value of the material for most purposes. As the bonding strength of the clay is high and as the drying shrinkage is moderate, the ware dries safely in any of the common types of driers. The green strength of the body also permits factory handling with little breakage. The Clarion clay is refractory, ranking in the intermediate heat duty class. It is low in carbonaceous matter and hence oxidizes rapidly at a red heat. It has a long burning range and moderate fire shrinkage which qualities insure a high yield of first-class ware from the kiln. The

body, well knit, has a clear attractive buff color. On the whole, the working qualities of the plastic clay from the Clarion horizon in Vinton County are all that may be desired.

The flint clay in the Clarion deposits in Vinton and Wilkesville townships resembles the Bolivar clay in eastern Ohio and western Pennsylvania. It is hard, brittle, and fine grained, has little or no plasticity, and is everywhere very siliceous. Locally it contains some detrimental impurities, the most conspicuous of which are small ore concretions and pyrite crystals. When properly bonded the working properties are good, as it has low drying and fire shrinkage, a long burning range, and a high overburning temperature. Its heat-resisting qualities are such that it ranks near the boundary between the high heat duty and the intermediate heat duty refractories. This clay is most valuable for general purpose fire brick. The following tests show the general properties of the Clarion clay in Vinton County.

The sample of Clarion clay taken on the Jesse White farm, near Hope Station, Brown Township, gave the following results:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	.92	K ₂ O	.078	} Al ₂ O ₃	1.00 {
Ignition loss.....	8.73	Na ₂ O	.022		
Silica, SiO ₂	54.29	CaO	.003		
Alumina, Al ₂ O ₃	29.37	MgO	.018		
Ferric oxide, Fe ₂ O ₃	1.98	FeO	.061		
Lime, CaO.....	.08				
Magnesia, MgO.....	.52	RO	.182		
Titanic oxide, TiO ₂	1.07				{ SiO ₂ 1.848
Phosphorus pentoxide, P ₂ O ₅	.05				{ TiO ₂ .036
Sodium oxide, Na ₂ O.....	.66				{ P ₂ O ₅ .002
Potassium oxide, K ₂ O.....	2.29				
Sulphur, S.....	.04				
Total carbon, C.....	.20				
Inorganic carbon, C.....	.00				
True specific gravity.....	2.64				

Physical tests

Working properties: The clay is plastic and smooth-textured. It machines well except for a few laminations which may be remedied by the addition of siliceous clay from the lower part of the deposit.

Drying behavior: This clay dries with perfect safety under any of the conditions ordinarily employed in drying such products.

Drying linear shrinkage.....4.0 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	2.8	16.25	Light buff
Cone 04	4.8	10.50	Light buff
Cone 02	5.5	7.90	Light buff
Cone 1	6.2	6.08	Medium buff
Cone 3	6.4	6.04	Medium buff
Cone 5	7.0	5.72	Medium buff
Cone 7	7.0	2.65	Light gray buff
Cone 9	7.2	2.58	Light gray buff
Cone 11	7.4	2.60	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cone 02 to above 11 (1,110 to above 1,350° C. or 2,030 to above 2,462° F.)

Total linear shrinkage at cone 7: 11.0 per cent.

Deformation temperature: Slightly less than cone 31 (1,685° C. or 3,065° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, hollow block, fire proofing, sewer pipe, and terra cotta. It has a long burning range and develops a good clear color.

Both the chemical analysis and the physical tests show this to be far above the average for a coal formation clay of the plastic type. Its range of usefulness is wide. Within this field it will give a high yield of first-class ware. The deposit is situated favorably for development.

On the property of George P. Drayer, located about one-half mile south of Hope Furnace, a sample of Clarion clay was taken by channeling the deposit, 8 feet 5 inches in thickness. The data obtained are given below:

Chemical analysis		Percentage oxide ratio			
Loss at 105° C.....	1.94				
Ignition loss.....	8.65				
Silica, SiO ₂	54.21	K ₂ O	.076	} Al ₂ O ₃	1.00 {
Alumina, Al ₂ O ₃	28.13	Na ₂ O	.007		
Ferric oxide, Fe ₂ O ₃	2.29	CaO	.000		
Lime, CaO.....	trace	MgO	.020		
Magnesia, MgO.....	.55	FeO	.081		
Titanic oxide, TiO ₂	1.98				
Phosphorus pentoxide, P ₂ O ₅	.01	RO	.184		
Sodium oxide, Na ₂ O.....	.21				
Potassium oxide, K ₂ O.....	2.14				
Sulphur, S.....	.004				
Total carbon, C.....	.17				
Inorganic carbon, C.....	.01				

Physical tests

Working properties: This clay is smooth and plastic and has a high bonding power. It laminates slightly in auger machines.

Drying behavior: It is easily and safely dried by any of the methods commonly employed.

Drying linear shrinkage.....3.7 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.5	15.2	Pink buff
Cone 04	4.3	9.2	Light buff
Cone 02	4.3	9.8	Light buff
Cone 1	5.1	8.2	Light buff
Cone 3	5.8	6.2	Buff
Cone 5	5.8	5.4	Buff
Cone 7	6.3	3.0	Gray buff
Cone 9	6.8	1.8	Gray buff
Cone 11	6.8	.2	Gray buff

Overburning temperature: Above Cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cone 1 to 11 (1,150 to 1,350° C. or 2,102 to 2,462° F.) It is steel hard at cone 1.

Total linear shrinkage at cone 7: 10.0 per cent.

Deformation temperature: Slightly below cone 29 (or slightly below 1,650° C. or 3,002° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, fire proofing, sewer pipe, and terra cotta. This clay burns to a good clear color.

By excluding some of the siliceous clay in the lower part of the deposit, the refractory qualities of the remainder may be increased perceptibly. It may be lowered also by increasing the silica content from material lying below the main stratum. Alterations in the batch are thus easily effected. The deposits are uniform in structure and character in this locality, are easily accessible, and have good mining conditions. In order to show the steadiness in quality of the member to the north, a sample of Clarion clay was also taken about one and one-half miles northwest of Hope Furnace on property of George P. Drayer. The results of the tests made are given below:

Chemical analysis		Percentage oxide ratio			
Loss at 105° C.....	1.22	K ₂ O	.090	} Al ₂ O ₃ 1.00 {	SiO ₂ 2.085
Ignition loss.....	8.02	Na ₂ O	.013		TiO ₂ .056
Silica, SiO ₂	56.89	CaO	.000		P ₂ O ₅ .006
Alumina, Al ₂ O ₃	27.28	MgO	.023		
Ferric oxide, Fe ₂ O ₃	1.75	FeO	.064		
Lime, CaO.....	trace		—		
Magnesia, MgO.....	.62	RO	.190		
Titanic oxide, TiO ₂	1.52				
Phosphorus pentoxide, P ₂ O ₅	.01				
Sodium oxide, Na ₂ O.....	.37				
Potassium oxide, K ₂ O.....	2.45				
Sulphur, S.....	.006				
Total carbon, C.....	.17				
Inorganic carbon, C.....	.07				

Physical tests

Working properties: The clay is plastic, smooth textured, and fine grained. It laminates but little in the machine.

Drying behavior: Ware made from this clay dries safely in any of the standard types of driers.

Drying linear shrinkage.....4.0 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.5	16.2	Pink buff
Cone 04	3.5	11.9	Pink buff
Cone 02	4.3	11.0	Pink buff
Cone 1	4.8	9.6	Light buff
Cone 3	5.3	7.5	Light buff
Cone 5	5.8	7.2	Buff
Cone 7	6.3	5.0	Buff
Cone 9	6.8	2.9	Gray buff
Cone 11	7.1	2.8	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cones 1 to 11 (1,150 to 1,350° C. or 2,102 to 2,462° F.) It is steel hard at cone 1.

Total linear shrinkage at cone 7: 10.3 per cent.

Deformation temperature: Slightly below cone 29 (slightly below 1,650° C. or 3,002° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, sewer pipe, fire proofing, and terra cotta. The burning range is long and the color is a clear buff free from specks.

On Sandy Run the Clarion clay disappears below drainage near the southern boundary of Section 11, Brown Township. The merit of the material is shown by the following determinations:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	.89	K ₂ O	.090	} Al ₂ O ₃ 1.00 {	SiO ₂ 2.123
Ignition loss.....	8.02	Na ₂ O	.012		TiO ₂ .044
Silica, SiO ₂	57.73	CaO	.003		P ₂ O ₅ .001
Alumina, Al ₂ O ₃	27.19*	MgO	.019		
Ferric oxide, Fe ₂ O ₃	1.69	FeO	.062		
Lime, CaO.....	.08				
Magnesia, MgO.....	.53	RO	.186		
Titanic oxide, TiO ₂	1.20				
Phosphorus pentoxide, P ₂ O ₅	.04				
Sodium oxide, Na ₂ O.....	.32				
Potassium oxide, K ₂ O.....	2.44				
Sulphur, S.....	.23				
Total carbon.....	.16				
Inorganic carbon.....	.00				
True specific gravity.....	2.64				

Physical tests

Working properties: This clay is plastic and smooth and works well through the dies of the machine without the development of objectionable cracks or laminations.

Drying behavior: The ware dries well in any type of drier.

Drying linear shrinkage: 3.5 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.3	14.05	Light buff
Cone 04	2.0	12.40	Light buff
Cone 02	3.4	10.04	Light buff
Cone 1	3.7	9.38	Light buff
Cone 3	4.0	7.32	Light buff
Cone 5	4.5	7.14	Light buff
Cone 7	5.0	5.46	Light gray buff
Cone 9	5.5	3.64	Light gray buff
Cone 11	5.5	1.61	Gray buff

Overburning temperature: Cone 11 (1,350° C. or 2,462° F.)

Best apparent burning range: Cones 02 to 11 (1,110 to 1,350° C. or 2,030 to 2,462° F.)

Total linear shrinkage at cone 7: 8.5 per cent.

Deformation temperature: Cone 30 (1,670° C. or 3,038° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, hollow block, fire proofing, and sewer pipe.

In its extension eastward in Brown Township the Clarion clay passes below drainage near Moonville in Section 7. The character of the material in this part of the field is apparent from the following determinations made on a sample collected near the former site of Coe's mill on the A. E. Kennard farm:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	1.32	K ₂ O	.058	} Al ₂ O ₃	1.00 {
Ignition loss.....	8.69	Na ₂ O	.019		
Silica, SiO ₂	55.90	CaO	.000		
Alumina, Al ₂ O ₃	28.05	MgO	.019		
Ferric oxide, Fe ₂ O ₃	1.87	FeO	.067		
Lime, CaO.....	trace				
Magnesia, MgO.....	.53	RO	.163		
Titanic oxide, TiO ₂	1.72				
Phosphorus pentoxide, P ₂ O ₅	.02				
Sodium oxide, Na ₂ O.....	.55				
Potassium oxide, K ₂ O.....	1.62				
Sulphur, S.....	.017				
Total carbon, C.....	.26				
Inorganic carbon, C.....	.06				

Physical tests

Working properties: The plastic properties of this clay are such that it works well in the machine.

Drying behavior: It dries satisfactorily in any type of drier.

Drying linear shrinkage: 3.5 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.5	16.0	Pink buff
Cone 04	3.7	11.8	Pink buff
Cone 02	4.2	11.4	Pink buff
Cone 1	4.6	10.5	Pink buff
Cone 3	4.9	9.5	Buff
Cone 5	5.1	8.8	Buff
Cone 7	5.8	6.5	Buff
Cone 9	6.5	3.2	Gray buff
Cone 11	6.3	3.3	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cones 3 to 11 (1,190 to 1,350° C. or 2,174 to 2,462° F.) It is steel hard at cone 3.

Total linear shrinkage at cone 7: 10 per cent.

Deformation temperature: Slightly below cone 29 (slightly below 1,650° C. or 3,002° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, sewer pipe, fire proofing, and terra cotta.

The standard uniform quality of the Clarion clay in the Brown Township field is established by the above tests of the five samples taken at various places throughout the most accessible parts of the area. As thus shown, it has real merit and usefulness. On the average it is superior to other plastic clays in the coal formations of Ohio. The alumina content, from 27 to 30 per cent, indicates its approach towards the kaolinitic type and its refractory character. The basic fluxes are low, totaling less than 5.60 per cent in any sample and averaging only 5.11 per cent for all. The acid fluxes are not excessive or especially detrimental as they consist nearly entirely of silica and titanite oxide. The burning range is long, thus insuring ease in burning with a high yield of first-class ware from the kiln. Both the drying and the fire shrinkages are moderate, indicating but little trouble from cracking, warping, and kiln marking. For a plastic clay the refractory qualities of the Clarion member in this field are especially good, as all of the samples deformed above cone 28 and the best reached cone 31. The excellence of this clay thus fits it for a wide variety of ceramic products.

Flint clay is becoming an asset of more importance from year to year as such material is not widely distributed throughout the Appalachian field, as many deposits are rapidly being depleted, as the demand for heat-resisting products is steadily increasing, and as no satisfactory substitute has as yet been discovered. On this account the flint clay deposits, although small, in Vinton and Wilkesville townships, are worthy of consideration as the basis for refractory ware. To determine the fitness of this material for useful purposes, both chemical and physical tests were made of representative samples. The data obtained from material collected on the land of the New York Coal Co. at Oreton are given below:

Chemical analysis		Percentage oxide ratio			
Loss at 105° C.....	1.38	K ₂ O	.001	Al ₂ O ₃	1.00 {
Ignition loss.....	9.67	Na ₂ O	.016		
Silica, SiO ₂	57.10	CaO	.002		
Alumina, Al ₂ O ₃	28.17	MgO	.004		
Ferric oxide, Fe ₂ O ₃	1.81	FeO	.054		
Lime, CaO.....	.05	MnO	.001		
Magnesia, MgO.....	.12				
Titanic oxide, TiO ₂	1.44	RO	.078		
Phosphorus pentoxide, P ₂ O ₅	.15				
Sodium oxide, Na ₂ O.....	.46				
Potassium oxide, K ₂ O.....	.02				
Manganous oxide, MnO.....	.01				
Sulphur, S.....	.04				
Total carbon, C.....	.05				
Inorganic carbon, C.....	.00				

Physical tests

Working properties: Short, sandy, difficult to mold.

Tempering water.....	13.91 per cent.
Drying linear shrinkage.....	1.18 per cent.
Drying volume shrinkage.....	3.59 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 08	1.62	4.78	29.83	Light cream
Cone 03	1.83	5.39	35.28	Light cream
Cone 01	1.64	4.83	34.24	Light cream
Cone 4	2.41	7.07	30.41	Light buff speckled
Cone 7	2.20	6.46	30.20	Light buff speckled
Cone 8	1.89	5.56	32.59	Light buff speckled
Cone 12	1.99	5.85	30.79	Light buff speckled
Cone 14	2.24	6.58	33.62	Light buff speckled
Cone 15	2.45	7.17	32.13	Light buff speckled

Overburning temperature: Above cone 15 (1,430° C. or 2,606° F.)

Best apparent burning range: Cones 8 to above 15 (1,290° C. to 1,430° C. or 2,354° F. to 2,606° F.)

Total linear shrinkage at cone 15: 3.63 per cent.

Deformation temperature: Cone 31 (1,685° C. or 3,065° F.)

Possibilities: High heat duty, siliceous clay refractories. Structure rather weak. A siliceous flint clay showing comparatively slight changes in shrinkage and porosity.

On the property of the Thompson Coal Co. near Campbell Tunnel, Section 19, Vinton Township, a sample of flint clay was taken under deep cover in a drift mine working the Clarion coal. The results of the tests are given below:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	.70	K ₂ O	.030	} Al ₂ O ₃	1.00 {
Ignition loss.....	9.11	Na ₂ O	.014		
Silica, SiO ₂	59.54	CaO	.006		
Alumina, Al ₂ O ₃	26.74	MgO	.005		
Ferric oxide, Fe ₂ O ₃	1.33	FeO	.050		
Lime, CaO.....	.17				
Magnesia, MgO.....	.12	RO	.105		
Titanic oxide, TiO ₂	1.40				
Phosphorus pentoxide, P ₂ O ₅	.06				
Sodium oxide, Na ₂ O.....	.38				
Potassium oxide, K ₂ O.....	.80				
Sulphur, S.....	.34				
Total carbon, C.....	.14				
Inorganic carbon, C.....	.02				
True specific gravity.....	2.52				

Physical properties

Working properties: The material works short owing to the mixture of flint and plastic clay. It has sufficient bonding power, however, to flow through the die without cracks or lamination.

Drying properties: It dries easily and safely.

Drying linear shrinkage: 2.50 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.0	17.17	Light buff
Cone 04	1.7	16.05	Light buff
Cone 02	2.5	13.27	Light buff
Cone 1	2.5	13.27	Light buff
Cone 3	3.0	13.27	Light buff
Cone 5	3.1	13.05	Light buff
Cone 7	3.5	12.30	Medium buff
Cone 9	3.5	12.50	Medium buff
Cone 11	3.5	12.00	Medium buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cones 7 to above 11 (1,270° C. to above 1,350° C. or 2,318° F. to above 2,462° F.)

Total linear shrinkage at cone 11: 6.0 per cent.

Deformation temperature: Cone 31 (1,685° C. or 3,065° F.)

Possibilities: High heat duty refractory ware. It lies just within the limits of this grade of refractory products but will make brick suitable for general purposes.

The analyses show that this flint clay belongs in the siliceous class as it contains about 25 per cent of free silica which component tends to keep the structure open and to counteract the high shrinkage of the clay substance. It is beneficial also in that it aids in resisting the action of acid slags. In this clay the basic fluxes are moderate in amount and common in kind. Locally the stratum contains some dif-fused pyrite which is objectionable as it localizes the iron and specks the ware. The heat-resisting qualities of the flint clay on the Clarion horizon, cone 31, place it just within the limit of the high heat duty class but careful selection will raise this slightly. The clay is best fitted for the manufacture of general purpose fire brick.

In a small field near Hamden Furnace in Clinton Township the Clarion clay is plastic and of excellent quality. From a representative sample taken at the Puritan plant of the McArthur Brick Co., the following data were obtained:

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	2.60	K ₂ O	.054	Al ₂ O ₃ 1.00	{ SiO ₂ 2.012 TiO ₂ .073 P ₂ O ₅ .001
Ignition loss.....	9.33	Na ₂ O	.007		
Silica, SiO ₂	54.33	CaO	.007		
Alumina, Al ₂ O ₃	27.01	MgO	.002		
Ferric oxide, Fe ₂ O ₃	2.38	FeO	.079		
Lime, CaO.....	.20	MnO	.000		
Magnesia, MgO.....	.05				
Titanic oxide, TiO ₂	1.98	RO	.149		
Phosphorus pentoxide, P ₂ O ₅	.03				
Sodium oxide, Na ₂ O.....	.18				
Potassium oxide, K ₂ O.....	1.46				
Manganous oxide, MnO.....	trace				
Sulphur, S.....	.05				
Total carbon, C.....	.48				
Inorganic carbon, C.....	.03				

Physical tests

Working properties: Good plasticity. Molding properties very good.

Tempering water.....23.48 per cent.

Drying linear shrinkage..... 5.96 per cent.

Drying volume shrinkage.....18.92 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 08	1.69	4.97	25.57	Light cream
Cone 03	3.63	10.50	26.44	Cream
Cone 2	4.65	13.31	22.53	Cream
Cone 4	5.77	16.34	20.71	Light buff
Cone 6	7.23	20.15	11.78	Medium buff speckled
Cone 9	7.63	21.19	10.19	Medium buff speckled
Cone 12	7.43	20.67	1.91	Gray speckled
Cone 14	7.39	20.57	0.59	Gray brown speckled

Overburning temperature: Above cone 14 (above 1,410° C. or 2,570° F.)

Best apparent burning range: Cones 6 to 14 (1,250° C. to 1,410° C. or 2,282° F. to 2,570° F.)

Total linear shrinkage at cone 14: 13.35 per cent.

Deformation temperature: Cone 29 (1,650° C. or 3,002° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, sewer pipe, and fire proofing.

This clay was formerly employed at the Puritan plant for the manufacture of general purpose fire brick by the stiff-mud process. It is used at present for making face brick which have good body structure, few defects, and an attractive buff color. In this locality the supply of high grade clay is large.

The Clarion clay in all of Vinton County shows good mining conditions. It is directly overlain by the Clarion coal which is about normal in development in Swan, Elk, Madison, Vinton, Wilkesville, and Clinton townships; but which is thin in Brown. In the former area the average measurement of clean coal from many determinations is 3 feet 7 inches and in the latter 1 foot 2 inches. The coal in turn is overlain by the Vanport limestone in the southern part of the county, by hard, gray shale in the central part, and by tough, fissile shale in the northeastern part, all sufficiently strong and resistant to afford safety to miners and to allow a good recovery of the materials below. Both clay and coal may be mined conveniently, at a low cost, from the same entry. The floor of the clay stratum is either a hard, siliceous clay or an argillaceous sandstone, which provide substantial footings for the supports necessary in mining. In the main fields the thickness of the Clarion clay varies from 5 to 10 feet but averages at least 7.

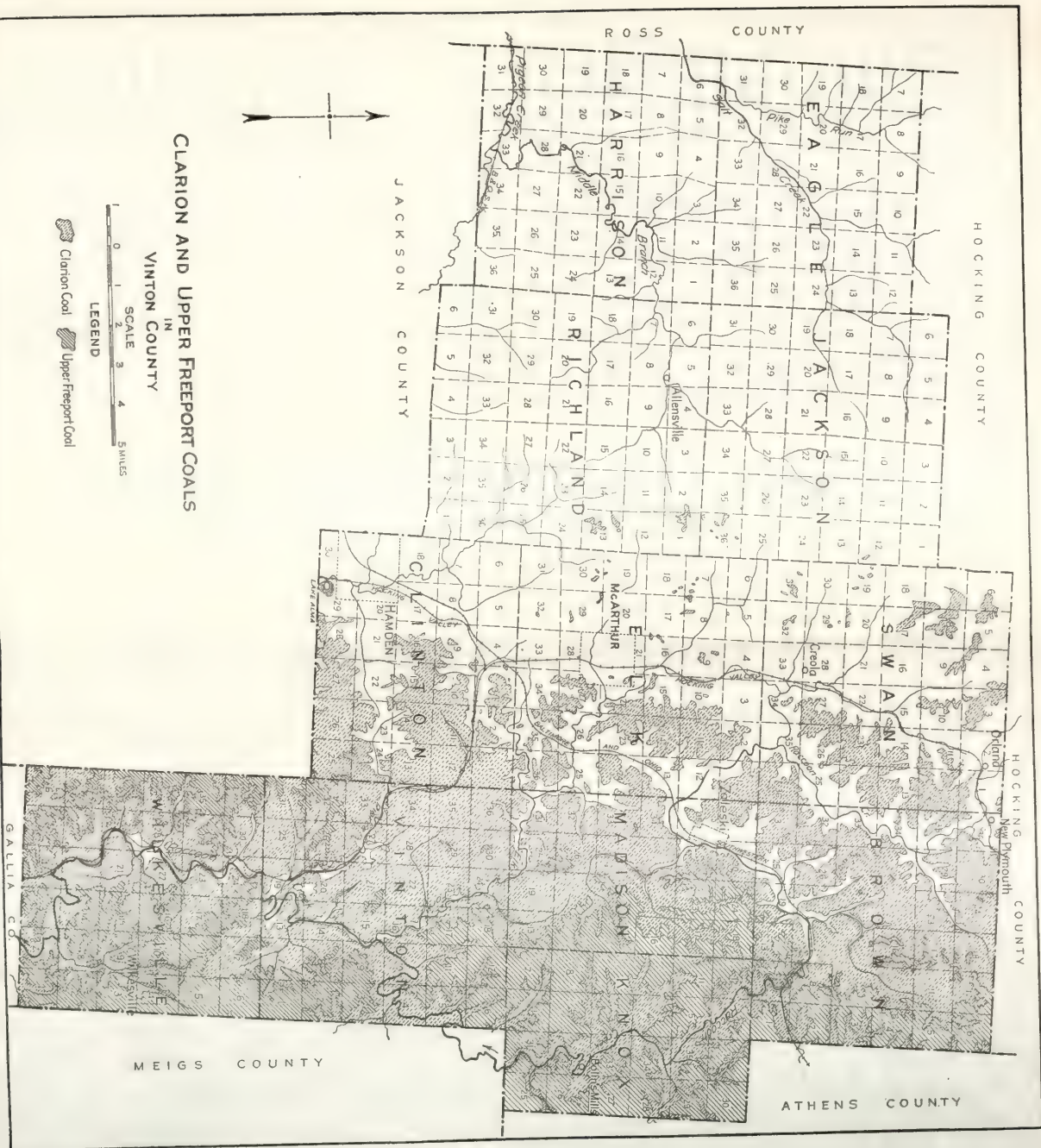
Under such favorable conditions at least 60 per cent of both coal and clay should be obtained by systematic mining. The approximate recovery per acre may be easily computed. The specific gravity of the Clarion clay is 2.64 and that of the associated coal 1.33. The weight per cubic foot, considering that of water to be 62.4 pounds, is therefore 165 pounds for the clay and 83 pounds for the coal. The yield of clay per acre, where the bed is 7 feet thick and 60 per cent may be recovered in mining, is 15,094 tons, which will produce 4,313,000 building brick. Similarly computed the yield of coal should be 3,887 tons in the main field where the bed is 3 feet 7 inches thick and 1,265 tons in Brown Township where it measures on the average only 1 foot 2 inches. The fuel required to manufacture a thousand building brick is nearly .75 ton with the best practice of continuous kilns and other heat-saving devices, but it is about 1.25 tons with the more wasteful methods now commonly employed. Under such conditions the coal necessary for making 4,313,000 brick, the quantity produced from one acre of Clarion clay 7 feet thick, is 3,235 tons by the first method and 5,391 tons by the second. These amounts are above by 652 tons and below by 1,504 tons the quantity of fuel, 3,887 tons, yielded by one acre of Clarion coal. In this region, however, additional fuel may be easily supplied by the Brookville, Winters, and Middle Kittanning members.

CLARION COAL

Stratigraphy and extent

The Clarion coal was named in 1858 by H. D. Rogers for deposits outcropping along the Clarion River in Pennsylvania,¹ where the thickness of the stratum is from 1 to 6 feet and its position below the Vanport or Ferriferous limestone is between 10 and 30 feet. In Ohio this member, although widely distributed, is best represented in the southern part, where in northern Lawrence, eastern Scioto, eastern Jackson, northwestern Gallia, and southern Vinton counties, it is very persistent and normally developed. In this field the average thickness of clean coal is nearly 3 feet 5 inches and that of coal and partings 4 feet 1 inch. The bed lies directly below the Vanport limestone from Mount Vernon Furnace in Decatur Township, Lawrence County, northward to Latrobe Furnace in Milton Township, Jackson County, but is separated from the limestone by 1 to 30 feet of shale from Latrobe Furnace northward to New Plymouth in Brown Township, Vinton County. Normally the member is made up of three benches of coal separated by two partings of impure clay; but locally, especially near the borders of the basin, the structure may change erratically. Further,

¹Rogers, H. D., First Geol. Survey of Pennsylvania, Vol. II, pp. 475-90.



the bed varies in thickness through the expansion or the diminution of coal benches and argillaceous partings and also through the addition or the disappearance of such strata. Throughout central and eastern Ohio the Clarion coal is only locally present and there poorly developed. The same is true in its extension southward from Lawrence County, Ohio, into eastern Kentucky. The field of most value is in northern Lawrence, eastern Jackson, and southern Vinton counties.

The Clarion is Vinton County's largest coal reserve. It extends over an area of approximately 170 square miles of which not more than 90 square miles should be considered productive territory, as the bed is thin or even wanting at many places. It is best represented in western Wilkesville, western Vinton, eastern Clinton, eastern Elk, western Madison, and southeastern Swan townships, where from more than 80 measurements, the thickness of clean coal is 3 feet 7 inches and that of coal and parting 4 feet 3 inches. Throughout the entire field in Vinton County the mean height of the bed from more than 140 determinations is 3 feet 2 inches of which 7 inches is parting. Normally the member is made up of three coal benches, lower, middle, and upper, with two partings, lower and upper. The average structure of the bed is shown below:

		Ft.	In.
<i>Clarion</i>	{ Coal, 8 inches to 2 feet 1 inch.....	1	2
	{ Clay, impure, 3 to 9 inches.....		6½
	{ Coal, 10 inches to 1 foot 11 inches.....	1	3
	{ Clay with pyrite, ½ to 3 inches.....		1½
	{ Coal, 5 inches to 1 foot 9 inches.....	1	2

In a few places in Vinton County an additional coal bench appears below the main bed. This is correlative with local lenses similarly placed in parts of Jackson and Lawrence counties. It varies in thickness from 2 inches to 1 foot 9 inches, in character from a rather pure coal to coaly shale, and in position from 3 inches to 1 foot 4 inches below the regular lower stratum.

The lower and middle coal benches are moderately free from irregular lenses of bone shale and shaly coal but the upper bench is in many places broken by such deleterious material. The entire bed contains more or less pyrite in the form of small nodules, thin plates, and disseminated crystals. The lower parting is clay, very siliceous in character, and usually highly impregnated with pyrite. On account of the presence of pyrite, it is called by the miners the "sulphur band." The upper parting is also a siliceous, pyritiferous clay but in addition it contains considerable organic matter in the form of thin layers of sooty carbon, carbonaceous shale, and impure coal.

The best bench for reference in determining the stratigraphic position of the Clarion coal in the geological column is the well known

Vanport limestone. The coal is separated from the limestone by shale the thickness of which is about 2 inches at Minerton in southern Wilkesville Township, 3 feet at Campbell Tunnel in southern Vinton, 2 feet at Puritan in southern Clinton, 22 feet at Vinton Furnace in southwestern Madison, 3 feet at McArthur in central Elk, 8 feet at the "divide" on the Chillicothe Road in northeastern Richland, and 18 feet in Section 10, Swan Township. The interval between the two beds is thus somewhat erratic but on the average it is nearly 8 feet. Where this interposed shale is thick, the Scrubgrass coal makes its appearance 3 to 12 feet above the Clarion member. In some localities the Vanport limestone is absent, thus necessitating the use of other beds for stratigraphic benches. With reference to some of these in Vinton County, the general position of the Clarion coal is 27 feet above the Zaleski flint, 53 feet above the Brookville or Newland coal, 46 feet below the Lower Kittanning coal, and 84 feet below the Middle Kittanning member.

As a whole the field has been but little depleted by mining. The deposits have been worked for shipment most extensively near Zaleski, Oretton, Radcliff, Hawk, Clarion, and Minerton. The member supplies also some domestic fuel over a wide area.

Brown Township.—In Brown Township the Clarion coal is above drainage along Raccoon Creek in the western and southern parts and along Sandy Run and its tributaries in the central part. In general the bed is thin, averaging only about 1 foot 2 inches, but with a variation from 1 inch to 4 feet. It is best developed in the southwestern corner of the township where formerly it was mined for shipment. Elsewhere in the township only small supplies of household fuel have been drawn from this source.

In the vicinity of New Plymouth, the Clarion coal is nearly 1 foot 6 inches thick and lies about 900 feet above tide. At an old mine in the southern part of Section 36, the following rocks were exposed:

	Ft.	In.
Shale, black.....	5	0
Shale, black, bony.....	2	6
Coal, good, <i>Clarion</i>	1	5
Clay, light, plastic.....	4	0
Shale and covered.....	22	7
Clay and covered.....	4	6
Shale, gray, siliceous.....	25	0
Shale, blue, fossiliferous.....	} <i>Lower Mercer</i>	6
Limestone, blue, nodular, fossiliferous.....		4

Along Twomile Run in sections 29 and 23, the member is persistent but thin. It is overlain by black shale and underlain by light, plastic clay. The exposures observed indicate the general thickness of the bed to be between 8 inches and 1 foot 6 inches. Along Raccoon

Creek in sections 34, 33, and 32, the deposits are similar in development and structure. Near the head of Strong Hollow in Section 31, the relation of the Clarion to overlying beds is well established, as shown in the following record:

	Ft.	In.
Sandstone, part covered.....	52	0
Shale and covered.....	5	0
Coal.....		11
Clay.....		2
Coal.....	2	9
Clay shale.....		1
Coal.....		8
Clay, impure.....	2	0
Shale and covered.....	16	0
Clay, dark, plastic.....	1	0
Clay, light, plastic.....	2	0
Coal blossom, <i>Lower Kittanning</i>	1	0
Clay and covered.....	8	0
Sandstone, massive.....	33	0
Shale, gray.....	4	0
Coal.....		11
Clay.....		4
Coal.....	1	6
Clay shale.....		1½
Coal.....		5

Middle Kittanning

Oak Hill

Clarion, altitude
853 feet

In this locality the Clarion coal was formerly mined in a large way by drifting. The usual thickness of the bed is reported by the miners to be 3 feet 4 inches and the maximum 4 feet 6 inches, but in central Section 25 it has dwindled to 1 foot 11 inches, which measurement is representative also along the tributary of Raccoon Creek in Section 26. At the Brewer Cut on the Baltimore and Ohio Southwestern Railroad in north central Section 19, the member is well exposed in the excavation. The lower bench of coal measures 7 inches, the shale parting 1 inch, and the upper bench of coal 1 foot 8 inches. The fuel is of good quality. The member is overlain by 6 feet of black, fissile shale and this in turn by 1 foot 3 inches of Scrubgrass coal. In the deep hollow in southern Section 19, the Clarion coal was well exposed along the stream bed where it had been stripped for local needs. The measurements secured are recorded below:

	Ft.	In.
Shale, black, fissile.....	2	0
Coal, good.....	1	6
Clay shale.....		2
Coal, good.....	1	1

Clarion, altitude
745 feet

At this place the Clarion member lies 97 feet below the Middle Kittanning coal and about 275 feet below the Brush Creek flint. The stratum is persistent but thin along Little Sandy Run where its ele-

vation is 750 feet at the mouth of the stream and 830 feet near the headwaters. In general it consists of a single layer of coal about 1 foot 4 inches thick. Along Sandy Run in central Brown Township, the Clarion horizon is well marked by a thin bed of coal associated with thick deposits of plastic clay and hard, carbonaceous shale. The coal varies in thickness from 1 inch to 1 foot 5 inches but averages only about 8 inches. Its position in the Allegheny formation is shown in the following section taken at Hope Furnace:

	Ft.	In.
Sandstone, soft, friable.....	40	0
Shale, dark, irregular.....		5
Coal, bony.....	} <i>Middle Kittanning</i>	6
Clay, impure.....		3
Coal, good.....		4
Clay, impure.....		1
Coal, good.....		5
Shale and covered.....	20	0
Clay, light, plastic, with ore nodules in lower portion, <i>Oak Hill</i>	7	0
Shale, gray, siliceous.....	8	6
Coal, <i>Lower Kittanning</i>	1	6
Clay, light, plastic.....	6	0
Clay, light, very siliceous.....	2	0
Sandstone, shaly to massive.....	18	0
Sandstone, massive, soft.....	29	0
Covered.....	4	0
Clay shale, dark.....	1	0
Ore, irregular, nodular.....		3
Shale, dark, carbonaceous.....	3	1
Coal, good, <i>Clarion</i> , elevation 726 feet.....		8
Clay, light, plastic.....	9	0

Along Raccoon Creek from Hope to beyond Moonville, the member lying not far above drainage is also lacking in development as the thickest deposits measure not more than 1 foot 3 inches. The intervals to overlying beds of prominence are usually 7 feet to the Scrub-grass coal, 50 feet to the Lower Kittanning coal, and 84 feet to the Middle Kittanning bed. As thus shown by the various sections, the outstanding features of the Clarion coal in Brown Township are the fairly uniform thinness of the bed, its direct association with black, carbonaceous shale and with good, plastic clay, and the absence of its usual companion, the Vanport limestone. Its value is small unless mined as an adjunct with the clay.

Swan Township.—Although widely distributed in Swan Township, the Clarion coal becomes important in only a few localities in the eastern half, where it has been mined both by stripping and by drifting for small supplies of domestic fuel. The roof is usually a black, carbonaceous shale; but in places this is replaced by gray shale or by sandstone. The member varies not only in thickness but in structure

as well, for it may be represented by one, two, or three benches of coal. The Vanport limestone, the common datum to which the Clarion coal is usually referred, is present in but few places.

Near New Plymouth in Section 1, the Clarion coal outcrops about 900 feet above tide. Where exposed along the road near the village, it has the following measurement:

	Ft.	In.
Shale, black, fissile.....	2	0
Coal, good.....	1	6
Clay shale		3
Coal, fair.....		2

Clarion

In the vicinity of Mt. Pleasant in sections 3 and 4, this coal has been mined in a small way for many years for a part of the local fuel supply. The member has fair thickness but is somewhat impure in the basal portion. The following section, taken in a mine on the property of Amos Garrison, is representative of the deposits in this locality:

	Ft.	In.
Shale, black, fissile.....	2	0
Coal, good.....	1	5½
Clay, dark.....		1½
Coal, good.....	1	2
Coal, bony.....		1
Coal, hard.....		6

Clarion

Locally the bed thickens to nearly 4 feet. Small mines are also operated in a desultory way in south central Section 3 where on the George Cherry farm it was sampled. (For analysis, see page 246.) The record follows:

	Ft.	In.
Shale, black.....	2	2
Coal, sampled.....	1	8
Clay, rejected.....		2
Coal, sampled.....		11
Coal, bony, rejected.....		8
Clay floor.		

Clarion

The Clarion member is overlain by black shale in which the Scrub-grass coal is interbedded. In northwestern Swan Township the bed is generally thin and the deposits are confined to high knobs on the main ridges. In central Section 10 a number of small mines have been operated from time to time. In this locality the bed, lying 930 feet above tide, is reported to be about 3 feet thick and to be divided near the middle by a thin layer of clay. Its position is nearly 22 feet below the Vanport limestone, which is thin, nodular, and uncertain. The Clarion member shows equal development along the ridges in sections 11 and 12 with an improvement through the addition of a

third bench of coal in sections 23 and 24. At a drift mine on the property of Harriet M. Schlotterback in north central Section 23, the following record was secured:

	Ft.	In.
Shale, black, bony.....	2	0
Coal, good.....	} Clarion, altitude 910 feet	8
Coal, bony.....		3
Clay with thin coal bands.....		7
Coal, good.....		11
Clay, impure.....		1½
Coal, good.....	1	2
Shale, dark, coaly.....		8
Clay, light.....	2	0

The bed here has the thickness and structure normal to it in the main field in southern Vinton, eastern Jackson, and northern Lawrence counties. It lies about 76 feet below the Middle Kittanning coal. Near the road in northeastern Section 27, the Clarion member is mined by George Wyckoff to supply the local trade. The following measurements were taken well under deep cover:

	Ft.	In.
Shale, black, fissile.....	3	0
Coal, rough.....	} Clarion, altitude 910 feet	2
Clay, dark.....		5
Coal, good.....		9
Clay, impure.....		1
Coal, good.....		4
Clay, siliceous.....	1	0

Although not large, the field of Clarion coal in Swan Township is ample to supply the local needs for many years. Mining conditions are good as the roof is generally a tough, black shale. The area of most importance lies between the Hocking Valley Railway on the west and Raccoon Creek on the east.

Jackson Township.—In Jackson Township, the Clarion coal is confined to a few high knobs and ridges in the southeastern corner. The bed outcrops at an elevation of about 1,030 feet. It is usually accompanied by the Vanport member, represented here by buhrstone. The Clarion deposits show normal development and are drawn upon for small supplies of household fuel. The following record, taken on the farm of George W. Hartley in southwestern Section 36, is representative:

	Ft.	In.
Shale, dark, very fossiliferous.....	2	0
Coal, rough.....	} Clarion	1
Clay shale.....		7
Coal, good.....		9
Clay, impure.....		1
Coal, good.....		8
Clay, plastic, good.....	6	6

In this locality the Clarion coal lies 8 to 15 feet below the buhrstone of the Vanport member, and 30 to 40 feet above the fossiliferous shale and shaly limestone of the Putnam Hill. The bed is directly overlain by shale bearing a large marine fauna and correlative with such material observed at many places in Elk, Clinton, and Vinton townships.

Richland Township.—Although confined to small areas along the ridges in northeastern Richland Township, the Clarion coal is noteworthy in that it has good thickness, regular structure, and normal relationships. The deposits are confined most largely to sections 1, 2, 12, and 13, where small drift mines have been operated for many years. The areas, however, are not yet exhausted. Near the “divide” on the McArthur-Chillicothe road in sections 1 and 2, small quantities of fuel are regularly drawn from the Clarion member to supply the immediate vicinity and the area to the west. In a mine on the Joshua Sands farm, the following section was secured:

	Ft.	In.
Limestone, <i>Vanport</i>	6	8
Shale and covered.....	8	0
Coal, rough.....	1	2
Clay shale.....		5
Coal, good.....	1	7
Clay, impure.....		1
Coal, good.....	1	3
Clay, siliceous.....	1	0

In this locality the coal and limestone are separated by shale varying from 6 to 10 feet in thickness. The Vanport member here assumes the definite features that it has in the main field in southern Vinton, eastern Jackson, and northern Lawrence counties. The largest area of Clarion coal in the township is present on the main ridge in central Section 13 where it is worked by drifting. At a mine on the property of John Reynolds, Jr., the following strata were exposed:

	Ft.	In.
Limestone, <i>Vanport</i>	6	0
Shale, varies from 1 inch to 5 feet.....	2	0
Coal, rough.....		8
Shale with thin coal bands.....		6
Coal, good.....	1	10
Clay shale.....		2
Coal, good.....	1	0
Clay, siliceous, thins in places to 6 inches.....	2	3
Coal.....		8
Clay and covered.....	15	0
Shale with thin coal bands.....		6
Coal with shale partings.....		10
Coal, good.....	1	8

At this place the Clarion member is thus seen to be made up of four coal benches, which structure is not uncommon in small areas elsewhere in Vinton County and also in Jackson, Scioto, and Lawrence counties. The overlying limestone is unsteady, being replaced by sandstone or by impure flint.

Elk Township.—The Clarion member in Elk Township has regularly furnished a part of the local fuel supply since pioneer days and bids fair to contribute its portion for many years. It is widely distributed; but owing to the dip of the rocks, the bed is found only on high knobs in the western part of the township and about midway down the slopes of the hills in the eastern part. The field of most value and least depleted is east of the Hocking Valley Railway. The Clarion bed lies close to the Vanport limestone where this member is present. The average thickness of clean coal is nearly 3 feet 11 inches and that of coal and parting 4 feet 6 inches. In general mining conditions are fair.

On the Elijah Harrold farm in southeastern Section 1, the Clarion coal is mined by drifting for household purposes. The bed shows the following divisions:

	Ft.	In.
Shale, gray.....	10	0
Coal, rough.....	1	1
Clay, impure.....		5½
Coal, good.....	1	8
Clay, pyritic.....		1
Coal.....		10½
Clay, siliceous.....	1	0

Clarion, altitude 830 feet

The position of this coal is 71 feet below the Middle Kittanning coal. The member is regularly present at an elevation of 870 feet along the high ridge in Section 2. Formerly it was mined at a few places. The areas are small and unimportant in sections 3, 4, 5, 6, 7, 8, and 9. On the property of Stephen Cramm in central Section 11, the Clarion coal was well exposed. The record follows:

	Ft.	In.
Sandstone, massive.....	5	0
Coal, reported thickness, <i>Middle Kittanning</i>	3	0
Shale, sandstone, and covered.....	54	3
Shale, gray.....	15	0
Coal, rough.....	1	3
Clay shale.....		6
Coal, good.....	1	10
Clay shale.....		1
Coal, good.....	1	1
Clay, dark.....	2	0

Clarion, altitude 875 feet

In parts of sections 12, 13, and 14, the roof is a massive sandstone which locally replaces part or all of the coal. The deposits are con-

fined to small areas on high knobs in sections 15, 16, 17, 18, and 19. On the Margaret Morley farm in the southwestern corner of Section 20, the coal is mined by stripping. Its position with reference to the Brookville coal is shown in the record given below:

	Ft.	In.
Shale, weathered.....	5	0
Coal, shaly.....		11
Clay, dark.....		5
Coal, bony.....		3
Coal, good.....	1	8
Clay, impure.....		1
Coal, fair.....	1	6
Clay, light, plastic, good.....	7	0
Shale and covered.....	23	6
Ore, siliceous, small kidneys.....		8
Shale, gray, siliceous.....	9	0
Shale, gray, fossiliferous, <i>Putnam Hill</i>	1	0
Coal, weathered, <i>Brookville</i>	1	0
Clay, plastic, good.....	5	0

Clarion, altitude 950 feet

For many years McArthur has drawn a part of its fuel supply from the Clarion deposits in Section 22. On the Jacob Morgan farm, the lower bench of coal measures 1 foot 1 inch, the pyritic parting 1 inch, the middle bench of coal 1 foot 7 inches, the clay parting 6 inches, and the upper bench of coal 1 foot. This member lies only a few feet below the Vanport limestone, 41 feet below the Lower Kittanning coal, and 89 feet below the Middle Kittanning bed. The overlying limestone is locally replaced by sandstone which there forms the roof of the coal. The Clarion member is regularly present but somewhat erratic in thickness in sections 23 and 24. Surface exposures indicate more normal development in Section 25 where it outcrops at an elevation of 780 feet. It is mined in a small way by Elmer Sims in central Section 26. The following record, taken under deep cover, is representative:

	Ft.	In.
Shale, gray.....	3	0
Coal, rough.....	1	1
Clay, carbonaceous.....		5
Coal, good.....	1	6
Clay shale.....		1
Coal, good.....	1	3
Clay, siliceous.....	1	0

Clarion

Near by the Vanport limestone makes its appearance only a few feet above the coal. In Section 27 the Clarion member is worked extensively by the McArthur Brick Co. for factory purposes. From a number of measurements in their mines the average thickness of clean coal is 4 feet and that of coal and partings 4 feet 9 inches. Domestic fuel is also produced by Truman Dixon at whose mine a sample was

cut for testing. (See analysis, page 246.) The thickness and structure of the bed are shown below:

	Ft.	In.
Shale, gray	3	0
Shale, gray, very fossiliferous, <i>Vanport</i>	3	6
Coal, good, sampled	} <i>Clarion</i>	8
Coal, bony, rejected		5
Clay, impure, rejected		5
Coal, good, sampled		7
Clay, rejected		1
Coal, good, sampled	1	3

Locally the Vanport limestone in nodular form appears along with the fossiliferous shale. The Clarion member lies 56 feet above the Brookville and Newland coal which has been mined also in a small way. In sections 28, 29, 30, 31, 32, and 33, the bed retains good thickness but the areas are small and now largely exhausted. It supplies household fuel on the farm of Ellsworth Waxler in northwestern Section 35. The beds exposed are shown below:

	Ft.	In.
Limestone, <i>Vanport</i> , not full thickness	3	0
Covered	10	0
Shale, gray	3	0
Coal, rough	} <i>Clarion</i> , altitude 840 feet	4
Clay, dark		5
Coal, good		6
Clay shale		1
Coal, good		8
Clay, plastic, siliceous	2	0

In this locality the Clarion coal is separated from the overlying Vanport limestone by 10 to 20 feet of shale, a part of which is in many places very rich in marine fauna. The limestone, however, is unsteady through lack of deposition and through replacement by sandstone. Further, the Clarion member lies about 20 feet above the Winters coal and 45 feet below the Lower Kittanning bed. Outcrop exposures indicate deposits of value in Section 36. In a ravine on the property of the Vinton Coal and Iron Co. in the northeastern part of Section 36, the following record was secured:

	Ft.	In.
Ore, irregular		4
Limestone, gray, <i>Vanport</i>	7	0
Shale, gray, parts covered	22	4
Coal, rough	} <i>Clarion</i> , altitude 760 feet	4
Clay, dark		4
Coal, good		8
Clay, impure		1
Coal, good		11

The small areas of thick Clarion coal in Elk and southeastern Swan townships may be considered as the northern extension of the main productive field in southern Ohio. It here exhibits the marked features such as steadiness in thickness, orderliness in structure, regularity in quantity, and conformity in association that it has elsewhere in the basin to the south. It likewise gradates northward into an erratic and impoverished form, more characteristic of that found in central and eastern Ohio.

Madison Township.—In Madison Township the Clarion coal appears above drainage along Raccoon Creek in the northwestern part, along Wheelabout Creek from Zaleski to Prattsville in the central part, along Elk Fork in the southwestern part, and along Flat Run in Section 13. The bed is persistent but fitful. It varies in thickness from a few inches to more than 6 feet. Likewise its unsteadiness is shown in that it may be represented by one, two, three, or even four coal benches which also lack symmetrical development. The companion bed, the Vanport limestone, is present only in the southern part of the area.

Along Raccoon Creek in Section 30, the Clarion member is made up of two coal benches averaging less than 2 feet 6 inches in thickness. It is overlain by black, fissile shale and underlain by light, plastic clay. The bed outcrops along the hillsides at an elevation of about 785 feet. In a local mine in Strong Hollow in north central Section 36, the following record was secured:

	Ft.	In.
Shale, gray.....	2	0
Coal, rough.....	1	2
Clay, impure.....		7
Coal, good.....	1	8
Clay shale.....		1
Coal, good.....		6
Clay, siliceous.....	1	6

In this locality the Clarion coal was formerly mined for shipment as it was also in the central part of the same section. Its position is about 85 feet below the Middle Kittanning member. In its extension southward into Section 35, the bed thins locally through diminution of some of the coal benches or through loss of the lower stratum. A decrease is shown in the measurements given below which were taken in a small mine on the property of Catherine Driscoll in the north central part of the section:

	Ft.	In.
Shale, dark.....	3	0
Clay shale, gray.....	1	6
Coal, fair.....	1	8

	Ft.	In.
Clay, impure.....		1
Coal, good.....		10
Coal, bony.....		$\frac{1}{2}$
Coal, good.....		7

Clarion, altitude 830 feet

Where mined along the road southwest of Zaleski in Section 35, the member consists of a lower coal bench, 7 inches thick, a shale parting $2\frac{1}{2}$ inches, and an upper coal bench, 1 foot 5 inches. The deposit is overlain by a black, fissile shale above which the Scrubgrass coal is found. For many years a part of the fuel supply for Zaleski has been drawn from the Clarion deposits in Section 29. At the mine of Trace, Rider, and Plummer, a sample was cut for testing (see analysis, page 247). The section is given below:

	Ft.	In.
Shale.		
Coal, sampled.....	1	7
Shale, rejected.....		1
Coal, sampled.....	1	0
Clay.		

Clarion

Other measurements taken in this locality show similar development and structure. The average thickness of clean coal is 2 feet 4 inches. Little change is evident in Section 35 where it was formerly mined at a few places. This member shows a decided but erratic increase in thickness along Wheelabout Creek from Zaleski to Prattsville, where its position is not far above drainage throughout the entire course. The bed has been mined rather extensively for neighborhood fuel. At the George Weaver mine one and one-half miles southeast of Zaleski, a sample was taken for testing. (See analysis, page 247.) Where channeled the bed has the thickness given below:

	Ft.	In.
Shale, black.....	1	0
Coal, sampled.....		10
Pyrite, local, rejected.....		$\frac{1}{2}$
Coal, sampled.....		9
Pyrite, rejected.....		$1\frac{1}{2}$
Coal, sampled.....		$7\frac{1}{2}$
Clay, rejected.....		$3\frac{1}{2}$
Coal, sampled.....		4
Clay, rejected.....	1	$5\frac{1}{2}$
Coal, sampled.....	1	2
Bone shale, rejected.....		2
Coal, sampled.....		5

Clarion

East of this on Wheelabout Creek near the mouth of a northern tributary, the Clarion coal was well exposed on the farm of Grover Dixon. The thickness of the lower bench is 1 foot 2 inches, that of

the clay parting 2 inches, and that of the upper bench 1 foot 5 inches. It is overlain by a hard, fissile shale and underlain by a siliceous clay highly impregnated with carbonaceous matter. The outcrop is just above the stream bed at an elevation of 720 feet. At Prattsville the Clarion coal lies near the level of the flood plain. The following section, which is representative, was taken on the property of Orval Lewis:

	Ft.	In.
Shale and covered.....	3	0
Coal, <i>Scrubgrass</i>	1	6
Shale, black, hard.....	3	8
Coal, good.....	1	5
Shale with pyrite.....	1	2
Coal, good.....		2

} *Clarion*, altitude, 740 feet

At Prattsville an attempt was made to strip the Clarion coal with a steam shovel. On account of water and the thinness of the bed, the results were not successful. The lack of orderliness in the Clarion member is shown in the following record taken on the property of Kate Kelly in central Section 32:

	Ft.	In.
Shale, gray.....	10	0
Shale, dark, carbonaceous.....	3	6
Coal, hard, bony.....	1	4
Coal, good.....		4
Clay, siliceous.....		8
Coal, fair.....		0
Clay, siliceous.....		0

} *Clarion*

In this mine the thickness of the coal benches and that of the clay parting vary considerably along different parts of the entry. Near by on the property of the Mohio Coal Co., the lower bench of coal has contracted to 1 foot 6 inches, the clay parting to 7 inches, and the upper bench of coal to 1 foot 2 inches. The Clarion member is above drainage along Elk Fork in the southwestern part of the township. Its elevation is 760 feet in western Section 31 and 700 feet in southwestern Section 19. Here as elsewhere in Madison Township, the deposits show erratic development, expanding from 1 foot or less to 6 feet or more. In an old mine in north central Section 31 on land of the Vinton Coal and Iron Co., the following record was secured:

	Ft.	In.
Shale, gray, with small ore nodules.....	15	0
Coal, fair.....	1	2
Shale.....	1	$\frac{1}{2}$
Coal, bony.....		$1\frac{1}{2}$
Clay, dark.....		4
Coal, good.....		6
Clay with pyrite.....		1

} *Clarion*

	Ft.	In.
Coal, good.....	1	.2
Clay, siliceous.....		10
Coal, good.....	1	2.
Clay, siliceous.....	1	0

In the vicinity of Vinton Furnace, the position of the Clarion coal is about 25 feet below the Vanport limestone and its thickness 4 feet 9 inches. From surface exposures the bed is of less value in sections 25 and 19. On Flat Run in the southern part of Section 13, it measures not more than 1 foot 2 inches. In this locality the Clarion coal is closely overlain by flint, representing the Vanport member.

Knox Township.—In Knox Township the Clarion coal appears above drainage in only a small area along Raccoon Creek in the northern part of Section 12. The deposits are similar to what they are in adjacent parts of Brown Township. The general features are shown in the following record taken along a small western tributary of Raccoon Creek lying in north central Section 12:

	Ft.	In.
Sandstone, massive.....	15	0
Shale, gray.....	2	6
Coal, <i>Scrubgrass</i>	1	1
Shale, black, hard, carbonaceous.....	5	7
Shale, bony.....		3
Coal, good, <i>Clarion</i> , altitude 720 feet.....	1	2
Clay and covered.		

The position of the Clarion coal here is about 45 feet below the Lower Kittanning coal and 85 feet below the Middle Kittanning. In this locality the clay associated with the Clarion coal is of high quality.

Vinton Township.—The Clarion is by far the most important coal bed appearing at the surface in Vinton Township. For many years it has supplied fuel for local domestic needs and some for shipment. The reserve yet easily available is large. The member is above drainage along Pierce Run in sections 35, 34, 33, 27, 21, 36, 20, and 19; along Raccoon Creek in sections 10, 9, 15, 14, 13, and 19; along Elk Fork in sections 24, 23, 17, and 16; and along Alman Run in sections 28 and 22. The bed has normal development in the southern part of the township but is erratic and uncertain in the northern part. From many determinations in the main field the respective measurements are lower bench of coal, 1 foot 1 inch; lower parting, 1 inch; middle bench of coal, 1 foot 3 inches; upper parting, 7 inches; and upper bench of coal, 1 foot 4 inches. Mining conditions are generally good as the roof is a tough shale and the floor a siliceous clay.

Along the stream in north central Section 36, the Clarion coal outcrops at an elevation of 725 feet. The bed, however, appears to be thin, through replacement of the upper benches by a massive sand-

stone. It is poorly represented also along Elk Fork and Flat Run in Section 24. The disturbance in the deposition of the Clarion member by current action is well shown along the cut of the Hocking Valley Railway in the west central part of Section 34, where locally only thin, irregular lenses of coal appear at the base of the sandstone. Near Oron in the southwestern part of this area, the bed, however, has normal development and has been mined at a number of places. In the old Hanging Rock mine a sample was cut by Orton in 1900 for testing. (See analysis, page 248.) Near by in the opening of the Kinwood Coal Co., the member has the thickness and structure given below:

	Ft.	In.
Shale, gray.....	2	0
Coal, fair.....	1	4½
Shale, carbonaceous.....		½
Coal, fair.....		1
Clay, dark, carbonaceous	1	6
Coal, good.....		4
Clay shale, black.....		1
Coal, good.....		6½
} Clarion, altitude 770 feet		

This mine is connected by a switch to the Hocking Valley Railway but its capacity is small. Along Alman Run in central Section 28, the Chicago-Oron Company stripped a small area of Clarion coal with a steam shovel. The record secured follows:

	Ft.	In.
Sandstone, soft.....	12	0
Shale, gray.....	5	0
Coal, fair.....	1	4
Coal, bony.....		2
Clay, impure.....	1	5
Coal, good.....		2
Clay shale.....		½
Coal, good.....	1	4
Clay, siliceous.....	1	0
} Clarion, altitude 720 feet		

Locally in this vicinity the overlying sandstone replaces the shale and a part of the Clarion coal. This member was also mined by this company in the southern part of the same section, where the bed measures 4 feet 11 inches in thickness and the clean coal 4 feet 3 inches. It is overlain by the Vanport limestone in patchy development. The interval of separation is from 12 to 16 feet. Along Elk Fork in Section 16, the Clarion member appears near the level of the flood plains, or about 670 feet above tide. Several small mines are operated to supply fuel for neighborhood use. In that of John Burns in the central part of the section, the following measurements were secured:

	Ft.	In.
Shale, gray.....	12	0
Coal, rough.....	1	4
Clay, impure.....		7
Coal, good.....	1	4
Clay, with pyrite.....		1
Coal, good.....	1	7
Clay, siliceous.....	1	0

In this locality the bed varies from 3 feet.6 inches to 5 feet in thickness. In its extension eastward into Section 10 the Clarion coal disappears below the waters of Raccoon Creek near Eakin's Mill where it is reported to be about 4 feet thick. It is accompanied also by the Vanport limestone with characteristic features. Somewhat similar conditions are found along Raccoon Creek in Section 15 where the following record, taken at the mine of John Canode, is approximately representative:

	Ft.	In.
Limestone, <i>Vanport</i>	6	0
Shale, gray, varies from 4 to 12 feet.....	5	6
Coal, rough.....	1	5
Clay, impure.....		5
Coal, good.....	1	2
Clay, with pyrite.....		1
Coal, good.....		7

These members appear in the stream bed, at an elevation of 710 feet, in central Section 21 where some fuel has been obtained by stripping. In the vicinity of Oreton in the northern part of Section 33, the Clarion coal has been mined in a large way for many years, and formerly it was further prepared for the market by washing. One of the largest consumers was the Alma Cement Company at Wellston. In the mine of the Vinton Coal Company a sample was cut for testing by Edward Orton, Jr. in 1900. (See analysis, page 248). The record measured by him follows:¹

	Ft.	In.
Coal, bony, with pyrite lenses, rejected....		2
Coal, upper bench, sampled.....	1	4
Shales and coal, rejected.....		9
Coal, middle bench, sampled.....		11
Shale, rejected.....		1½
Coal, lower bench, sampled.....		11
Clay, not measured.		

These mines are now owned and operated by the New York Coal Company. The average of several measurements in this locality shows the following thickness and structure: coal, lower bench, 1 foot

¹Geol. Survey Ohio, Bull. 9, p. 176.

4 inches; clay parting, 1 inch; coal, middle bench, 1 foot 2 inches; clay and bony coal, 7 inches; and coal, upper bench, 1 foot 4 inches. At a few places an additional lens of coal appears below the main deposit. This is shown in a section which is given below and which was taken at the Eagle Tunnel on the Hocking Valley Railway:

	Ft.	In.
Sandstone, massive.....	10	0
Coal, rough.....	1	3
Clay with thin coal bands.....		8
Coal, good.....	1	2
Clay with pyrite.....		1
Coal, good.....	1	3
Clay shale.....	1	3
Coal, shaly.....		2
Clay shale.....		7
Coal, stray bench.....	1	0
Clay, impure.....	3	0
Sandstone, part argillaceous.....	17	0
Track level, H. V. Ry.		

Near Oretion the Vanport limestone is locally present 4 to 18 feet above the Clarion coal. The intervening material is a gray, siliceous shale. In some areas both the limestone and the shale are replaced by a massive sandstone which there forms the roof of the Clarion member. Further, where the erosion action was severe a part of the coal bed is also wanting. This effect is shown in the following record taken on the D. L. White property west of Radcliff in east central Section 26:

	Ft.	In.
Sandstone, massive.....	20	0
Clay with thin layers of bony coal.....	1	3
Coal, bony.....		4
Coal, good.....	1	0
Clay, impure.....		5
Coal, good.....	1	4
Clay, siliceous.....	1	0

Such impoverishment is also shown locally near Radcliff in Section 20. The Clarion member, however, again appears with more normal characteristics along Raccoon Creek in Section 14, where it outcrops near the level of the flood plain at an elevation of about 650 feet and where it has been mined at a number of places for local fuel. The following record taken in the opening of J. E. Bacus is representative:

	Ft.	In.
Shale, gray.....	5	0
Coal, rough.....	1	6
Clay, impure.....		5
Coal, good.....	1	3
Clay with pyrite.....		1
Coal, good.....		7
Clay, siliceous.....	1	0

The Clarion member retains good thickness along Raccoon Creek in Section 13 and has been mined for shipment along the Hocking Valley Railway in Section 19. Where worked by the Reinhart Coal Company at Campbell Tunnel its stratigraphic relations and thickness are as given below:

	Ft.	In.
Sandstone, massive, argillaceous.....	20	0
Limestone, gray.....	3	7
Flint, shaly.....	1	0
Shale, black, bony.....	2	7
Coal, rough.....	1	5
Clay with thin coal bands.....		8
Coal, good.....	1	1½
Clay with pyrite.....		1½
Coal, good.....	1	2

Vanport

Clarion, altitude 650 feet

The measurements are much the same in the mine of the Thompson Coal Company near by and in that of the Syndicate Coal Company in the north central part of the section. With few exceptions in this locality the roof of the coal is a hard, black shale overlain by the Vanport limestone, and thus is not only safe for the workmen but allows a high yield of coal. In places in the mines a fourth bench of coal, 4 to 10 inches thick, is present from 6 inches to 3 feet below the main deposit. This extra stratum is correlative with that similarly placed at Eagle and Vinton furnaces in Vinton County, at Buckeye Furnace and Roads in Jackson County, and at Washington, Pioneer, and Olive furnaces in Lawrence County. Owing to its poor quality and to the thick parting intervening, this lower bench of coal is at few places mined except incidentally in removing floor material to gain height in the main entrance. The Clarion member is above drainage along the tributary of Raccoon Creek in the northern part of Section 25. Not far from the Haggerty School the following record was secured in a small drift mine on the Lincoln Furnace property:

	Ft.	In.
Sandstone.....	20	0
Limestone, gray, <i>Vanport</i>	6	3
Shale, black, bony.....	2	2
Coal, rough.....	1	0
Clay with thin coal bands.....		5
Coal, good.....	1	2
Clay with pyrite.....		2
Coal, good.....	1	2

Clarion, altitude 700 feet

As shown by the various sections given, the field of workable Clarion coal in Vinton Township is large as the bed shows normal thickness and good continuity throughout most of the central and southern portion. Only small areas near Oreton and Radcliff have been depleted

by mining. The field is well cut by valleys along which the bed is open for attack. This coal is a resource of value.

Wilkesville Township.—In Wilkesville Township the Clarion coal appears at the surface along Raccoon Creek in sections 24, 23, 22, 28, 21, 27, 26, and 20; along Rockcamp Run in Section 30; along Indiancamp Run in Section 28; and along Karr Run in Section 27. The coal enters the township above Hawk at an elevation of 640 feet and passes below cover in the central part of Section 20 at 610 feet. The bed is persistent and regular throughout the field. The average of many measurements taken at various places along the outcrop shows coal, lower bench, 1 foot 2 inches; clay, lower parting, 1½ inches; coal, middle bench, 1 foot 2 inches; clay, upper parting, 6½ inches; and coal, upper bench, 1 foot 6 inches. The roof material changes in different parts of the field. The coal may be directly overlain by the Vanport limestone, by black, carbonaceous shale, or by a massive sandstone, the strength of which is sufficient to provide safety for the workmen and a good yield of fuel. In this field the Clarion coal has been mined for shipment for many years at Hawk, Clarion, and Minerton, but the area exhausted is not large and is confined to the front along Raccoon Creek. From drill records the member appears to have good continuity and thickness under deep cover in the eastern part of the township. Its position is about 37 feet below the Lower Kittanning coal and 76 feet below the Middle Kittanning bed.

On Rockcamp Run in the western part of Section 30, the Clarion member passes below drainage at an elevation of 685 feet. At a small local mine in the central part of this section the following record was secured:

	Ft.	In.
Flint, light, impure.....	3	0
Limestone, siliceous.....	2	10
Shale, weathered.....		6
Flint, shaly.....		5
Shale, black, fissile.....	2	6
Coal, rough.....	1	2
Coal, bony.....		3
Clay, impure.....		7
Coal, good.....	1	2
Clay with pyrite.....		2
Coal, good.....	1	2
Clay, siliceous.....	1	0

In the vicinity of Hawk in Section 24, this member has been mined for shipment for many years. North of the village it is worked by the Black Hawk Coal Company and the Beech Grove Coal Company, the latter mining about 175 tons per day. The bed, normal in structure, is made up of about 3 feet 9 inches of clean coal and 9 inches of

clay partings. It is overlain by black, fissile shale above which is present a massive, coarse-grained sandstone. In 1900 a sample of Clarion coal was cut by Edward Orton, Jr., in the mine of Elmer Keck and Company. The bed where channelled has the thickness shown below:

	Ft.	In.
Sandstone.		
Coal, sampled.....	1	3
Clay, rejected.....		11
Coal, sampled.....	1	1½
Clay with pyrite, rejected.....		1½
Coal, sampled.....	1	2½
Clay, siliceous.		

Clarion

Most of the coal produced in this locality has been used for steam generation in stationary and locomotive boilers for which purpose, if properly cleaned, it is very satisfactory. The quantity produced is neither large nor steady. South of Hawk near the mouth of Rockcamp Run, the Clarion member is mined for household fuel and by the Shafer Coal Company for the general market. In the mine of the latter company the following representative measurements were secured:

	Ft.	In.
Sandstone, massive.....	10	0
Limestone, part flinty.....	4	6
Flint, shaly.....		4
Shale, gray, hard.....		4
Shale, bony, black.....	1	11
Coal, rough.....	1	7
Clay, impure.....		7
Coal, good.....	1	3
Clay with pyrite.....		2
Coal, good.....	1	2
Clay, siliceous.....	1	0

Vanport

Clarion, altitude, 665 feet

Along Raccoon Creek in Section 23, the Clarion, about 630 feet above tide, is persistent and regular. It has been mined in either a small or a large way at many places. The following record, taken along the stream west of the Hocking Valley Railway in the southern part of the section, shows the general structure of the coal and the character of the overlying rocks:

	Ft.	In.
Shale, gray.	3	0
Limestone, gray, upper part flinty, <i>Vanport</i>	6	6
Shale, gray.....		3
Shale, hard, black, bony.....		10
Coal, fair.....	1	4
Coal, bony.....		5
Clay, impure.....		6
Coal, good.....	1	2
Clay shale.....		1½
Coal, good.....	1	2

Clarion



A.—Ruins of Hope Furnace in Brown Township. Built in 1853.



B.—An old mine of Clarion coal with Vanport limestone for the roof, at Hawk.

On the north tributary of Indiancamp Run in south central Section 29, the Clarion coal at drainage level is reported to be 4 feet 2 inches thick. The roof is black, fissile shale above which the Vanport limestone is regularly present. In this locality the Clarion coal lies about 29 feet below the Lower Kittanning coal, 76 feet below the Middle Kittanning coal, 166 feet below the Upper Freeport coal, and 251 feet below the Brush Creek limestone. The member appears just above drainage at an elevation of 670 feet, along Indiancamp Run in eastern Section 34. It is also level-free along this stream and along Raccoon Creek in Section 28. At the mine of Frank Stanton in the southeastern part of the section the following measurements were obtained:

	Ft.	In.
Limestone, part flinty, <i>Vanport</i>	6	2
Coal, rough.....	1	9
Clay with bands of bony coal.		2
Clay, impure.....		5
Coal, good.....	1	4
Clay with pyrite.....		1
Coal, good.....	1	1
Clay, siliceous.....	1	0

Clarion, altitude 640 feet

Large mines were formerly operated in the Clarion member at the village of Clarion in Section 22. The coal has been worked in a small way also south of Mt. Olive Church on an eastern tributary of Raccoon Creek. In the vicinity of Minerton the bed has been mined extensively by the Lawler Coal Company for many years. In one of their openings a sample for testing was cut in 1900 by Edward Orton, Jr. (See analysis, page 248.) The section follows:

	Ft.	In.
Limestone.		
Coal, sampled.....	1	6½
Shale, rejected.....		6½
Coal, sampled.....	1	2
Shale, rejected.....		1½
Coal, sampled.....	1	1
Clay, impure.		

Clarion

In this locality the Clarion coal is directly overlain by the Vanport limestone, the thickness of which is 6 to 8 feet. From several determinations the average measurement of clean coal in the Clarion member is 3 feet 9 inches and that of the partings 8 inches. The coal disappears below the bed of Raccoon Creek in central Section 20.

Clinton Township.—In Clinton Township the Clarion coal is confined to the area east of the old valley extending from Dundas to Hamden. Owing to the dip of the rocks to the east, the position of the bed above tide is approximately 860 feet in Section 3; 890 feet in

Section 29; 770 feet in Section 1; and 760 feet in Section 25. The member is usually normal in thickness, structure, and association. In small areas, however, it is partially or even completely replaced by sandstone. Most of the mines are small, supplying fuel for local needs only. In sections 1 and 2 the Clarion member is unsteady, giving way locally to sandstone. Near Dundas in Section 3, it is more regular and has been mined at a few places where it is reported to be about 4 feet thick. On the property of Eva Rush in the northeast corner of Section 9, the following measurements were obtained in a small drift mine:

	Ft.	In.
Shale, dark	2	0
Coal, rough	1	7
Clay with thin bands of bony coal		7
Coal, good	1	5
Clay with pyrite		1
Coal, good	1	2
Clay, siliceous	1	0

} *Clarion*, altitude 845 feet

In this locality the Vanport member represented by buhrstone is present 5 to 10 feet above the Clarion coal. In Section 10 the bed is persistent in extent but somewhat variable in thickness, owing to replacement of the upper bench or to the lack of development of the lower one. This condition is also evident in Section 11 where at the shipping mine of A. K. Walker in the northeastern part the following measurements were secured:

	Ft.	In.
Sandstone, massive, parts covered	31	0
Shale and clay, irregular	5	0
Coal, rough	1	1½
Clay shale	1	3
Coal, good	1	5
Clay, impure		1
Coal, good		3
Clay, dark	2	0

} *Clarion*, altitude 760 feet

At this place the Clarion lies about 40 feet below the Lower Kittanning coal and 30 feet above the Winters coal. It is unsteady also in sections 12, 13, and 14 but more normal in sections 15 and 16, where it has been mined at a few places. In an old mine on the ridge in northern Section 21, the following relations were observed:

	Ft.	In.
Limestone, <i>Vanport</i>	6	0
Shale, gray	7	2
Coal, rough	1	5
Clay, impure		6
Coal, good	1	3
Clay with pyrite		1
Coal, good		7
Clay, plastic	6	0

} *Clarion*

Surface exposures indicate that the Clarion coal is of value in sections 22, 23, and 24. Along the stream in the southwestern part of Section 25, this coal was formerly mined for shipment. The combined thickness of the three coal benches is 3 feet 9 inches and that of the two clay partings 8 inches. The coal is separated from the Vanport limestone by gray and black shale varying from 1 to 10 feet in thickness. The deposits show similar thickness and arrangement in sections 26 and 27. The following record, taken at the mine of the McArthur Brick Company, is representative of the Clarion member in Section 28:

	Fr.	In.
Limestone, <i>Vanport</i>	10	0
Shale, black, bony.....	1	6
Coal, rough.....	1	2
Clay with thin coal bands.....		6
Coal, good.....	1	4
Clay with pyrite.....		1½
Coal, good.....		11
Clay, plastic.....	9	0

} *Clarion*

In this locality the Clarion coal lies 45 feet below the Lower Kittanning coal and 74 feet below the Middle Kittanning. It is drawn upon for most of the fuel used in the manufacture and in the burning of clay products at the Puritan works of the McArthur Brick Company. The roof is a hard, black shale overlain by the Vanport limestone or by a massive sandstone, thus allowing a high yield of fuel. The supply of Clarion coal yet available in Clinton Township is ample to meet the local needs for many years.

Economic value

The Clarion is the largest fuel reserve in Vinton County, being followed by the Middle Kittanning, Brookville, Winters, Quakertown, Lower Kittanning, and Upper Freeport coals. In kind it is an ordinary bituminous coal. Owing to its coking properties, it burns freely only while the volatile matter is being expelled. The coke residue is consumed slowly unless forced draft is used. The Clarion coal ranks low in quality as it is high in sulphur and ash and slightly below the average in heating value. On ignition it produces much soot which tends to choke the flue system. The ash is easily fusible and quite corrosive as it is high in bases and in sulphur. Further, the partings are so placed in the bed and so tender in character that some deleterious material is usually added to the fuel in mining. If properly cleaned the Clarion coal may be used satisfactorily for steam generation, brick burning, and general heating. The value of the member is enhanced by the fact that in large areas it is underlain by clay of high purity and

in some localities it is directly overlain by the Vanport limestone, useful for many purposes. Either of these materials may be mined easily and cheaply in conjunction with the coal. The quality of the Clarion coal is shown by the analysis given below:

The Clarion coal was sampled in July, 1902, by B. A. Eisenlohr at the mine of George Cherry in Section 3, Swan Township. The coal in the upper bench is much harder than that in the lower one. The sample, cut about 60 feet from the outcrop, is representative of the fuel in this locality.¹

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	66.26	69.68	Moisture.....	4.90	.00
Hydrogen.....	5.40	5.11	Volatile matter.....	39.16	41.18
Oxygen.....	12.71	8.78	Fixed carbon.....	45.79	48.15
Nitrogen.....	1.23	1.29	Ash.....	10.15	10.67
Sulphur.....	4.25	4.47			
Ash.....	10.15	10.67		100.00	100.00
	100.00	100.00			
			As received	Moisture free	
Calorific value.....	{	Calories	6,845	7,198	
		B. t. u.	12,321	12,956	

At the mine of J. T. Dickson in Section 27, Elk Township, a sample for testing was cut from a fresh surface by E. E. Somermeier in September, 1901. At this place the coal had 50 feet of covering.²

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	67.17	70.66	Moisture.....	4.95	00.00
Hydrogen.....	5.40	5.10	Volatile matter.....	39.17	41.21
Oxygen.....	13.28	9.34	Fixed carbon.....	46.56	48.98
Nitrogen.....	1.30	1.37	Ash.....	9.32	9.81
Sulphur.....	3.53	3.72			
Ash.....	9.32	9.81		100.00	100.00
	100.00	100.00			
			As received	Moisture free	
Calorific value.....	{	Calories	6,914	7,274	
		B. t. u.	12,445	13,093	

¹Geol. Surv. Ohio, Fourth Series, Bull. 9, pp. 201-2. It is Clarion and not Middle Kittanning coal as designated in Bulletin 9.

²Geol. Surv. Ohio, Fourth Series, Bull. 9, p. 183.

The Clarion coal where mined by Trace, Rider, and Plummer in Section 29, Madison Township, was sampled well under the hill by E. E. Somermeier in September, 1901. The data follow:¹

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	67.92	71.51	Moisture.....	5.02	.00
Hydrogen.....	5.48	5.18	Volatile matter.....	39.90	42.01
Oxygen.....	12.98	8.97	Fixed carbon.....	46.11	48.55
Nitrogen.....	1.33	1.40	Ash.....	8.97	9.44
Sulphur.....	3.32	3.50			
Ash.....	8.97	9.44			
				100.00	100.00
	100.00	100.00			

		As received	Moisture free
Calorific value.....	{ Calories	6,960	7,328
	{ B. t. u.	12,528	13,190

On Wheelabout Creek one and one-half miles southeast of Zaleski, the Clarion coal was regularly worked in September, 1922, by George Weaver. Well under deep cover a sample was taken under favorable conditions by W. Stout and Miles Ogan. The results of the test are given below:

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	65.56	68.87	Moisture.....	4.80	.00
Hydrogen.....	4.96	4.65	Volatile matter.....	40.56	42.60
Oxygen.....	12.33	8.46	Fixed carbon.....	42.21	44.34
Nitrogen.....	1.21	1.27	Ash.....	12.43	13.06
Sulphur.....	3.51	3.69			
Ash.....	12.43	13.06			
				100.00	100.00
	100.00	100.00			

		As received	Moisture free
Calorific value....	{ Calories	6,567	6,898
	{ B. t. u.	11,821	12,417

Fusion of ash....	{ Incipient	1,399° C. or 2,550° F.
	{ Complete	1,432° C. or 2,610° F.

At the Hanging Rock mine in Section 34, Vinton Township, a combined sample was cut from two rooms, the face of the coal being fresh in each. The work was done by Edward Orton, Jr., in August, 1900.²

¹Geol. Surv. Ohio, Fourth Series, Bull. 9, pp. 183-4.

²Geol. Surv. Ohio, Fourth Series, Bull. 9, p. 174.

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	68.52	72.14	Moisture.....	5.02	.00
Hydrogen.....	5.49	5.19	Volatile matter.....	40.31	42.44
Oxygen.....	13.69	9.72	Fixed carbon.....	46.52	48.98
Nitrogen.....	1.28	1.35	Ash.....	8.15	8.58
Sulphur.....	2.87	3.02		100.00	100.00
Ash.....	8.15	8.58			
	100.00	100.00			
			As received	Moisture free	
Calorific value....			{ Calories	6,961	7,329
			{ B. t. u.	12,530	13,192

A sample of Clarion coal was taken by Edward Orton, Jr., in August, 1900, at the mine of the Vinton Coal Company located in Section 33, Vinton Township. The results of the test are given below:¹

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	64.91	68.05	Moisture.....	4.61	.00
Hydrogen.....	5.36	5.08	Volatile matter.....	41.35	43.35
Oxygen.....	12.05	8.33	Fixed carbon.....	42.94	45.01
Nitrogen.....	1.30	1.36	Ash.....	11.10	11.64
Sulphur.....	5.28	5.54		100.00	100.00
Ash.....	11.10	11.64			
	100.00	100.00			
			As received	Moisture free	
Calorific value....			{ Calories	6,760	7,087
			{ B. t. u.	12,168	12,756

At the Lawler mine near Minerton in Section 27, Wilkesville Township, the Clarion member was sampled by Edward Orton, Jr., in August, 1900. The analytical data follow:²

<i>Ultimate</i>			<i>Proximate</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	67.17	70.46	Moisture.....	4.52	.00
Hydrogen.....	5.44	5.07	Volatile matter.....	40.10	42.00
Oxygen.....	13.03	9.43	Fixed carbon.....	46.53	48.73
Nitrogen.....	1.28	1.34	Ash.....	8.85	9.27
Sulphur.....	4.23	4.43		100.00	100.00
Ash.....	8.85	9.27			
	100.00	100.00			
			As received	Moisture free	
Calorific value....			{ Calories	6,904	7,231
			{ B. t. u.	12,427	13,015

¹Geol. Surv. Ohio, Fourth Series, Bull. 9, p. 176.

²Geol. Surv. Ohio, Fourth Series, Bull. 9, p. 178.

The above samples are representative of the Clarion coal in the Vinton County field. Although having objectionable qualities, this fuel may be used conveniently for the development of power and heat and should aid in the promotion of industries in the region. The quantity available is large. The bed is favorably situated for attack over a wide area and has good mining conditions. The Clarion coal in Vinton County is a reserve of importance for future needs.

SCRUBGRASS COAL

Stratigraphy and extent

The name Scrubgrass was applied in 1858 by H. D. Rogers of the Pennsylvania Survey to a coal bed outcropping along Scrubgrass Creek in the southwestern part of Venango County, Pa. He states: "We here for the first time meet with an interposed seam of coal between the limestone (Vanport) and the Clarion bed. It is never more than 20 inches thick, is slaty, and frequently immediately underlies the limestone. It may perhaps be considered as an upper member of the Clarion coal, subdivided by the intercalation of shale."¹ In later reports of the Pennsylvania Survey the Scrubgrass or Upper Clarion coal is frequently mentioned in the geology of Mercer, Venango, Lawrence, Butler, Clarion, Beaver, and Allegheny counties.

In Ohio the Rogers classification was first used by Edward Orton in 1884 when in his general section he placed both the Clarion and Scrubgrass members in the interval below the Ferriferous (Vanport) limestone. He described them as follows: "Two coal seams occur below the Ferriferous (Vanport) limestone and help to mark the general horizon. The place of one of these seams, which is known as the Scrubgrass coal, is directly beneath the limestone. The second or Clarion coal is found from 15 to 30 feet below the limestone. Both seams fail for the most part in all of the northern border of the Ohio field."²

In this State the Scrubgrass coal is best developed and most clearly defined in Vinton County where in some areas it appears with considerable regularity in shales interposed between the Clarion coal and the Vanport limestone where the latter stratum is present. The position of the member is somewhat variable, lying in some places near the Clarion coal and elsewhere near the Vanport limestone. On the average, however, its place is about 8 feet above the base of the coal bed and 3 feet below the limestone.

The Scrubgrass bed is not a split from the Clarion coal but is a distinct unit formed in small local basins not long after Clarion time.

¹Pennsylvania Geol. Survey, Vol. II, p. 573.

²Geol. Surv. Ohio, Vol. V, pp. 10, 17, 162.

At no place does it combine directly with the Clarion member nor in any way is it responsible for the thickening or the thinning of the underlying stratum. It is, with few exceptions, present only where the roof of the Clarion coal is a dark, carbonaceous shale. The usual order of deposition is Clarion coal, carbonaceous shale, Scrubgrass coal, gray shale, and Vanport limestone or sandstone. The Scrubgrass member is absent where gray, siliceous shale, above the average in thickness, directly overlies the Clarion bed. The Scrubgrass has little or no clay associated with it whereas the Clarion member is always underlain by thick deposits of pure clay. Thus during Scrubgrass time the swamp conditions were favorable for the presence of carbonaceous matter as coal but not for the alteration of the argillaceous sediments into clay. Although the Scrubgrass coal is thin, impure, and uncertain, it deserves recognition as a separate member. It is locally present in Brown, Swan, Madison, Knox, Vinton, and Wilkesville townships, Vinton County, and in Starr and Washington townships, Hocking County.

Although far from persistent, the Scrubgrass coal is found with considerable regularity along Twomile Run, Sandy Run, Raccoon Creek, and their larger tributaries throughout central Brown Township. It is generally absent in the western tier of sections and is below drainage in the eastern part. The stratigraphic relations of the Scrubgrass coal to other members is well shown in the following record taken along the road in the northwestern part of Section 23:

	Ft.	In.
Sandstone, soft, micaceous.....	75	0
Coal and partings, <i>Middle Kittanning</i>	4	4½
Covered.....	25	8
Coal, weathered, <i>Lower Kittanning</i>		6
Clay, plastic, light.....	9	6
Sandstone, massive, soft.....	33	0
Shale, gray, siliceous.....	7	4
Ore, nodular.....		1
Shale, dark gray, siliceous.....		10
Coal, shaly, <i>Scrubgrass</i>		8
Shale, dark, part covered.....	3	1
Shale, black, somewhat fissile.....	3	11
Shale, bony, blocky.....	1	3
Coal, <i>Clarion</i>		10
Clay, plastic.....	6	0

As thus shown in this locality the Scrubgrass member lies about 8 feet above the base of the Clarion coal, 55 feet below the Lower Kittanning coal, and 78 feet below the well developed Middle Kittanning member. The bed was observed at other places in this area. The thickness of the stratum varies from 6 inches to 1 foot 3 inches and the quality from a rather pure to a bony fuel. On Sandy Run in the south-

ern part of Section 11, the Scrubgrass coal appears near drainage level. The associated materials are shown in the record given below:

	Ft.	In.
Sandstone, shaly.....	3	0
Shale, gray, siliceous.....	10	0
Coal, somewhat bony, <i>Scrubgrass</i>	1	1
Shale, dark, carbonaceous, somewhat fissile.....	4	3
Shale, hard, blocky, cannel nature.....	1	8
Coal, good, blocky, <i>Clarion</i>		6
Clay, plastic, light.....	5	0
Clay, plastic, siliceous.....	2	0
Stream bed.		

Near the head of Little Sandy Run, the Scrubgrass coal is exposed along the banks of the stream at an elevation of about 830 feet. Where measured, it is 7 inches thick and is separated from the Clarion coal by 4 feet 5 inches of hard, carbonaceous shale. Near Hope Furnace small irregular lenses of Scrubgrass coal are present at the base of a massive sandstone which generally replaces the member. Conditions are similar near the mouth of Sandy Run and along Raccoon Creek in Section 14. The bed, however, is more persistent and better developed in Section 19. The following record, taken along Raccoon Creek in the northeastern part of the section, is representative:

	Ft.	In.
Sandstone, massive.....	15	0
Shale and covered.....	7	0
Shale, gray, siliceous.....	2	0
Coal, shaly, <i>Scrubgrass</i>	1	5
Shale, black, carbonaceous.....	5	8
Coal, good, <i>Clarion</i>	1	2

Near Hope Station the Scrubgrass member with fair development and regularity appears 6 to 10 feet above the Clarion member. On the property of Timothy Clifford, a lens of blackband ore appears in the shale underlying the coal. A section taken at this place is given below:

	Ft.	In.
Sandstone, massive, soft.....	37	0
Coal, shaly, <i>Scrubgrass</i>		1
Clay shale.....	1	2
Clay shale, soft.....	1	5
Ore, blackband.....	2	6
Shale, gray.....		8
Shale, black, bony.....		3
Coal, <i>Clarion</i>	1	1
Clay, plastic.....	6	2

Near by the Scrubgrass coal thickens to 1 foot. This deposit of blackband ore appears to be local. Nodular ore, however, is present

in the shale at a few places along Raccoon Creek between Hope and Moonville. It is low in iron and high in siliceous material. In the cut of the Baltimore and Ohio Southwestern Railroad in the west central part of Section 8, the following strata were well exposed:

	Ft.	In.
Sandstone, massive, coarse, soft	25	0
Disconformity, small.		
Shale, gray, siliceous	2	6
Ore, irregular, siliceous, <i>Vanport</i> , 4 to 10 inches		6
Shale, gray		8
Coal, irregular, bony, <i>Scrubgrass</i>	1	3
Shale, black, somewhat fissile	1	8
Ore, siliceous, irregular		4
Shale, dark, part fissile	5	4
Coal, good, <i>Clarion</i>	1	1
Clay, plastic	2	0

At this place the thickness of the *Scrubgrass* coal varies from 5 inches to 1 foot 4 inches and its position from 5 to 10 feet above the *Clarion* member. In the next cut east of the above, the upper coal and associated shale are replaced by the massive overlying sandstone. Along Raccoon Creek south of Moonville in Section 7, both coals are regularly present, the *Clarion* being about 1 foot 1 inch thick and the *Scrubgrass* 10 inches.

In Knox Township the *Scrubgrass* member is above drainage only along Raccoon Creek in the northern part of Section 12. Near the mouth of a tributary to the west, the following record was secured:

	Ft.	In.
Sandstone, massive	15	0
Shale, gray, siliceous	2	6
Coal, bony, <i>Scrubgrass</i> , altitude 720 feet	1	1
Shale, black, carbonaceous	5	7
Shale, hard, bony		3
Coal, good, <i>Clarion</i>	1	2

The position of the *Scrubgrass* coal here is approximately 41 feet below the Lower Kittanning coal, 89 feet below the Middle Kittanning coal, and 185 feet below the Upper Freeport. The *Vanport* limestone is absent, more from lack of deposition than from replacement.

The *Scrubgrass* member is present with fair continuity along Raccoon Creek, Wheelabout Creek, and Elk Fork in Madison Township. The underlying *Clarion* coal is about normal in development and the overlying *Vanport* limestone appears in isolated patches. Along the road southwest of Zaleski, the following beds were exposed:

	Ft.	In.
Sandstone, massive, soft.....	50	0
Coal, bony, <i>Scrubgrass</i>		10
Shale, black, carbonaceous.....	3	2
Coal, weathered.....	1	5
Shale.....	}	2½
Coal, good.....		
Clay, plastic.....	6	8

Clarion

Local deposits are also present east of Zaleski in Section 29 and south of Raccoon Creek in Section 34. In the hollow east of "The Pinnacle" both the *Scrubgrass* and *Clarion* members have been stripped in a small way for local fuel. The *Scrubgrass* is 1 foot 7 inches thick but shaly in character. Its position is about 6 feet above the *Clarion* member, the intervening material being black, carbonaceous shale. At the mine of Grover Dixon on Wheelabout Creek, the general relations of the beds are as shown below:

	Ft.	In.
Shale, gray, siliceous.....	5	0
Coal, shaly, <i>Scrubgrass</i>	1	6
Shale, dark, carbonaceous.....	6	10
Shale, hard, bony.....		6
Coal, good.....	1	5
Clay, impure.....	}	2
Coal, good.....		
Shale, carbonaceous, part covered.....	4	6
Sandstone, massive, argillaceous.....	4	0
Stream bed.		

Clarion

Except where replaced by sandstone, the *Scrubgrass* member is present along the tributary of Wheelabout Creek that extends southward to Prattsville, where the *Clarion* coal is at drainage level. On the property of Orval Lewis at this place, the following beds were exposed:

	Ft.	In.
Sandstone, soft, friable.....	10	0
Shale, gray.....	12	0
Coal, shaly, <i>Scrubgrass</i>	1	5
Shale, black, carbonaceous.....	4	2
Coal and parting, <i>Clarion</i>	3	6

On Elk Fork in sections 31, 25, and 19, the *Scrubgrass* coal and the associated carbonaceous shale appear to be absent. The interval from the *Clarion* coal to the Vanport limestone, or to the sandstone that locally replaces it, is made up of gray, siliceous shale. This condition also prevails to the west in Elk Township and to the south in most of Vinton Township. Near the bridge over Elk Fork in northern Section 16, Vinton Township, the *Scrubgrass* coal appears at the base

of a massive sandstone that replaces the Vanport member. The beds here exposed are shown in the following record:

	Ft.	In.
Sandstone, massive.....	15	0
Coal, bony, <i>Scrubgrass</i>		8
Shale and covered.....	6	0
Shale, dark, carbonaceous.....	5	4
Coal.....	1	4
Clay shale.....	1	3
Coal, part shaly.....	1	4

} *Clarion*, lower part well exposed

Along Raccoon Creek from Arbaugh to Hawk and along Pierce Run from Oreton to Radcliff, the *Scrubgrass* member was not observed, although locally some black shale is present above the *Clarion* coal. It appears to be wanting more through lack of deposition than through replacement by sandstone. In Wilkesville Township the *Scrubgrass* member was found at only one place, which is at the mine of the Beech Grove Coal Company just east of Hawk. The section taken is given below:

	Ft.	In.
Sandstone, massive.....	25	0
Coal, bony, <i>Scrubgrass</i>		10½
Clay, with thin coal bands.....		4
Sandstone with black shale partings.....		9
Shale, bony, black.....	2	6
Coal, rough.....	1	5
Clay, thins to 4 inches.....		6
Coal, good.....	1	2
Clay, with pyrite.....		1½
Coal, good.....	1	2
Clay, siliceous.....	1	0

} *Clarion*

South of this near *Clarion*, the *Clarion* coal and Vanport limestone are separated by only a thin layer of carbonaceous shale and at Minerton they lie in contact. In Clinton Township the *Scrubgrass* member was not observed.

Economic value

The *Scrubgrass* member in Vinton County is of more interest for its stratigraphic than for its economic features as the area is small, the stratum thin, and the quality poor. Aside from the local field in Brown and Madison townships, the deposits are patchy and uncertain. The average thickness of the bed from thirty measurements is 11 inches and the minimum and maximum 1 inch and 1 foot 7 inches respectively. The coal is everywhere shaly in character. The partings vary from thin, papery laminae to 1 inch or more. Such material is present throughout the entire bed. This coal also contains much sulphur in the form of pyrite and some in the form of organic sulphides. "Mother

coal" is regularly present in most of the deposits. The Scrubgrass member has been mined only along stream beds where the overburden has been largely removed by erosion. The quantity thus obtained is trifling. The member has little or no clay associated with it. The Scrubgrass member along with the associated black shale forms a good roof for the underlying beds, the Clarion coal and Clarion clay, which are economically important.

VANPORT OR FERRIFEROUS LIMESTONE

Stratigraphy and extent

This stratum was first named the Ferriferous limestone in 1858 by Henry D. Rogers of the first Geological Survey of Pennsylvania, where in the western part such deposits were conspicuous at many places. Regarding the member he states:¹ "The Ferriferous limestone is so called because, in many localities, a very valuable deposit of iron ore rests directly upon it, while in other localities the bed of limestone itself seems to be divided between carbonate of lime and carbonate of iron. This ore is accompanied by a species of chert called 'The Buhr-Stone' which is compact in its texture, externally gray, but light blue when newly fractured, and usually interposed between the limestone and the ore. The limestone is usually a blue carbonate of lime of compact structure; but it is often of gray-blue color, hard and solid, with a few fossils." In Ohio for like reasons the bed was named the Ferriferous limestone in 1870 by E. B. Andrews, as it carries upon its upper surface, sometimes adhering and sometimes separated by a little shale, an iron ore, which in Vinton, Jackson, Scioto, and Lawrence counties, is everywhere known as the limestone ore.² As the ore was largely used for iron smelting in the charcoal furnaces of the region, the underlying limestone was known as the Ferriferous. He also refers to it as the Grey limestone and as the Hanging Rock limestone. The former designation is made on account of its prevailing gray color and the latter on account of its being extensively worked near Hanging Rock in Lawrence County. The term Vanport, which is now in more common use, is from Vanport, Pennsylvania, where the bed is well exposed along a cut of the Pennsylvania Railroad.

In Ohio the most extensive and persistent field of Vanport limestone extends northward from the Ohio River through western Lawrence, eastern Scioto, eastern Jackson, and western Gallia counties to central Vinton. It is here a rather pure limestone with local lenses of flint or chert in the upper portion. The bed varies from 4 to 10 feet in thickness. Throughout the central part of the State in Hocking,

¹Rogers, H. D., First Geol. Surv. of Pennsylvania, Vol. II, part I, p. 491.

²Geol. Surv. of Ohio, Rep. of Progress, 1870, p. 61.

Perry, Muskingum, Coshocton, Holmes, Tuscarawas, and Stark counties, the deposits are generally small and either decidedly shaly or flinty in character. In general shale alone marks the horizon. In Mahoning County the member again shows more characteristic properties in that it is a rather pure limestone but it is patchy. The deposits, however, are much above the average in thickness. In Columbiana County the horizon is marked only by fossiliferous shale although near by at Vanport, Pennsylvania, it is again exceptionally well developed. In Ohio the southern field is by far the most important. In Vinton County the Vanport member is unsteady and in much of the area its place in the geological column is not marked even by fossiliferous shale. It is wanting both through lack of development and through replacement by massive sandstone. As a true limestone the deposits of most value are present along Raccoon Creek and its western tributaries in central Wilkesville Township, on the ridges in southeastern Clinton, along Pierce Run and Raccoon Creek in Vinton, along Flat Run in southeastern Madison, along the ridges in southeastern Elk, and on the main divide in northeastern Richland. Thin, isolated deposits are also found in Brown, Swan, and Jackson townships.

At Minerton in Wilkesville Township, the Vanport limestone lies directly upon Clarion coal, which is the condition in most of Jackson, Lawrence, and Scioto counties. In the remainder of the county, the two beds are separated by shale varying from a few inches to as much as 22 feet in thickness. The average position of the limestone is nearly 8 feet above the top of the coal or 11 feet above the base. The first prominent member above the Vanport limestone is the Lower Kittanning coal. The interval of separation of these beds varies from 19 to 73 feet but averages from more than fifty measurements about 45 feet 6 inches. Further, its position is about 84 feet below the Middle Kittanning coal, 38 feet above the Zaleski flint, and 64 feet above the Brookville coal.

The Vanport member in Vinton County may be represented by rather pure limestone, by cherty limestone, by chert or buhrstone, and by calcareous shale. Normally the entire bed is a sparingly fossiliferous limestone which is light gray, massive, and rather close and fine in texture. Locally, in the upper portion, irregular lenses of chert appear, sometimes so abundantly as to be the dominant material. This part is also in many places stained pink or red with iron oxides which are derived, through solution, from the ores and shales above and are precipitated by the limestone from the circulating waters. In a few localities, especially near McArthur, this member is represented by irregular, bowldery masses of light-colored, cellular chert which formerly was quarried at several places and dressed into buhrstone. The position of shaly phase of the Vanport is directly below the main limestone stratum although this may be absent from the section. These

shales are light gray to dark in color, are usually rather rich in fossils, and vary from decidedly calcareous to siliceous in composition. They are correlative with those found below the flint on Flint Ridge in Licking County, with those below the limestone near Frazeyburg in Muskingum County, and with those present alone along Little Beaver Creek in Columbiana County. Thus during Vanport time, the marine invasion first laid down argillaceous sediments in restricted areas over a wide basin. This was followed by conditions favoring the deposition of calcium carbonate over much of the floor and of siliceous matter in small, isolated patches.

The thickness of the Vanport member in Vinton County varies from less than 1 foot to more than 10 feet. Normally in the main field the deposits measure 4 to 8 feet and average nearly 6 feet. The stratum is usually thin where represented only by buhrstone and where present in isolated patches bordering the larger fields.

Brown Township.—As a true limestone the Vanport member is completely wanting in Brown Township. In the central and north-eastern parts of Section 25, scattered boulders of buhrstone were observed along the outcrop. The deposits are very patchy and the flint from 3 inches to 1 foot or more thick. Its position is 10 to 15 feet above the Clarion coal. Irregular lenses of iron ore also mark the horizon in parts of sections 19 and 13.

Swan Township.—Likewise the Vanport is poorly represented in Swan Township where it is due above drainage over a wide area. The horizon is only locally marked by either limestone, flint, or iron ore. On the ridges in the central part of Section 10, the following record was obtained:

	Ft.	In.
Shale and covered.....	15	0
Limestone, weathered, bowldery, <i>Vanport</i> , altitude 945 feet..	1	8
Shale, gray, parts covered.....	10	0
Shale, dark, parts covered.....	8	0
Coal and covered, old mine, <i>Clarion</i>	4	0

Near the summit of the knob—east of Creola in the central part of Section 34, the ore associated with this member was formerly mined by stripping. It is underlain by scattered boulders of gray limestone few of which are more than 1 foot thick. The elevation of the deposit is 940 feet above tide, and its position is about 15 feet above the Clarion coal and 104 feet above the Upper Mercer ore and flint. Local deposits of ore and flint are also present along the ridges in the southwestern part of the township.

Jackson Township.—Owing to the rise of the rocks to the west and north, the Vanport member is absent in all of Jackson Township except on a few high knobs in the southern part of Section 36, where its

elevation is nearly 1,030 feet. It is represented only by buhrstone, the thickness of which varies from 3 inches to 2 feet. The member is separated from the Clarion coal by 1 to 5 feet of dark, carbonaceous shale which locally is fossil bearing.

Richland Township.—In Richland Township the only deposits of the Vanport member worthy of consideration are present on the main dividing ridge in sections 1 and 13. They vary in character, however, from a rather pure, gray limestone to buhrstone of the usual type. On the "divide" just north of the Chillicothe-McArthur Road in Section 1, the Vanport member was quarried for road ballast. Where measured the bed is 6 feet 8 inches thick and is separated from the Clarion coal by 6 to 10 feet of gray shale with plant fossils. The material in the lower part of the deposit is of good quality but that in the upper part is decidedly flinty. In the southern part of Section 1, the common material marking the horizon is buhrstone, varying from 1 to 3 feet in thickness. In Section 13 the deposits vary in character from limestone to flint and in thickness from 1 to 6 feet. Locally the limestone lies directly upon the Clarion coal but generally it is separated from this stratum by 1 to 10 feet of shale. On the property of John Reynolds, Jr., small quantities of limestone have been burned for agricultural purposes. The elevation of the deposits is from 980 to 990 feet.

Elk Township.—In Elk Township the Vanport member is widely distributed but very unsteady except in the southeastern part where either limestone, flint, or fossiliferous shale is generally present on the horizon. In the central and northern parts of the township, only isolated patches of similar material are found. In the thicker deposits the stone is normal in character and similar to that in the main field in Jackson, Scioto, and Lawrence counties. Further, the flint closely resembles the cellular variety present on Flint Ridge northwest of Brownsville in Licking County. The associated ore is poorly represented.

Near the residence of H. J. Malone in the north central part of Section 1, about 10 inches of Vanport limestone is present nearly 32 feet above the Clarion coal and 22 feet below the Lower Kittanning member. The deposit is small as it was not observed elsewhere in this vicinity. Ore with some flint marks the horizon in the southeastern part of Section 10. In the northwestern part of the township, the member is absent except for small deposits of iron ore. A few boulders of limestone were observed near the summit of the ridge in the southern part of Section 19. South of this in Section 30 on the property of Charles Dayton, the member has excellent thickness and has been quarried and burned for agricultural purposes. A sample for testing was taken from the face of the quarry. (For analysis, see page 266.) The section follows:

	Ft.	In.
Soil.....	2	0
Limestone, <i>Vanport</i> , sampled.....	6	0
Covered.....	10	0
Coal blossom, <i>Clarion</i>	2	0
Shale and covered.....	24	7
Coal blossom, <i>Winters</i>	1	0

Along the ridge in Section 32, the member is represented by local deposits of cellular flint from a few inches to more than 2 feet in thickness. Its position is 5 to 10 feet above the *Clarion* coal and its elevation nearly 945 feet above tide. This material was formerly gathered from the surface and quarried extensively for buhrstone along the ridges in southwestern Section 28, eastern Section 29, northeastern Section 18, southeastern Section 7, and southwestern Section 8. Small bodies of flint are also present in adjacent areas, but they were little worked. At these old quarries the deposits are not now sufficiently exposed for measurement. The usual thickness, however, appears to be not more than 3 feet. The flint masses are irregular in shape, vary greatly in texture and solidity, and shade from light to red in color. Some are very open and loosely connected whereas the best grade, formerly employed for buhrstone, is somewhat cellular but firmly bonded. The deposits appear to have been formed through alteration of chert or calcareous flint by weathering agencies. Through solution the calcareous matter and iron oxides were removed and amorphous silica then precipitated to bond the residual fragments of flint. The deposits are all located along the ridges where the covering is thin and where the common, natural forces of modification are effective.

On the property of Jacob Morgan in the northeastern part of Section 22, small, irregular lenses of *Vanport* limestone are present at the base of a massive sandstone. Its position is only a few feet above the *Clarion* coal and about 35 feet below the Lower Kittanning coal. In Section 27 the member is more persistent but varies in character from hard limestone to impure flint and to calcareous, fossiliferous shale. The following section, taken near the plant of the McArthur Brick Company, shows the limestone and shale phases and their relation to the underlying *Clarion* coal:

	Ft.	In.
Shale, gray.....	3	0
Limestone, gray, hard, } fossiliferous.....	2	3
Shale, gray.....		7
Shale, black, fossiliferous.....	1	8
Coal, somewhat shaly.....		9
Clay, impure.....		8
Coal, good.....	1	6

Vanport, altitude 860 feet

Clarion

		Ft.	In.
Clay with pyrite.....	} <i>Clarion</i>		2
Coal, good.....		1	4
Shale and bony coal.....			1
Coal, bony.....			4

The limestone, where present, varies from 6 inches to 3 feet 6 inches in thickness and the fossiliferous shale from 4 inches to 4 feet. The shale contains a larger and better preserved marine fauna than the limestone. These deposits afford good collecting. In this locality only thin lenses of flint appear on the horizon but to the east in Section 26, the Vanport member shows a decided increase in thickness, especially of the limestone phase. Measurements taken on the ridge in the northeastern part of the area show the following relationships:

	Ft.	In.
Sandstone, massive.....	15	0
Disconformity, slight.		
Limestone, gray to pink, upper part locally ferruginous, <i>Vanport</i>	8	6
Shale and covered.....	16	6
Coal blossom, <i>Clarion</i>	1	0
Clay, siliceous.....	4	0
Shale with large ore nodules irregularly dispersed.....	11	0
Covered.....	9	0
Old mine, <i>Winters</i> coal, reported 2 to 4 feet thick.....	3	0

Near by on land of Allen Townsend, 6 feet of limestone was exposed. Locally, however, the bed is absent either through replacement by sandstone or through lack of deposition. The fossiliferous shale is also uncertain in extent and in character. The conditions are similar in Section 35. Near the head of the hollow in the south central part of Section 25, about 7 feet of good, gray limestone was observed at an elevation of 790 feet. This bed extends with little change across the northern part of Section 36, where near Elk Fork, it was formerly quarried rather extensively for flux stone for charcoal furnaces. A sample for testing (for analysis, see page 266.) was taken across the face of the old quarry. The measurements are given below:

	Ft.	In.
Limestone, flinty, excluded.....	1	0
Limestone, gray, hard, sampled.....	8	0
Limestone, not well exposed.		

At this place the bed is reported to be about 12 feet thick and of good quality except at the top. It is separated from the *Clarion* coal by nearly 22 feet of gray, siliceous shale. In the southern part of Section 36, the *Vanport* member is very patchy, being largely replaced by sandstone. The quantity of limestone easily available along Elk Fork

from McArthur to Vinton Furnace is sufficient to supply the wants for road building and agricultural purposes. Most of it is of good quality, comparing favorably with that in the main field in Jackson, Scioto, and Lawrence counties.

Madison Township.—The Vanport member is almost entirely absent in the northern part of Madison Township and only locally developed in the southern part, where along Elk Fork in the vicinity of Vinton Furnace it is represented by bowldery masses of good limestone and on Flat Run by irregular lenses of flinty material. Its absence is due more to lack of deposition than to replacement by sandstone. The deposits are suggestive of shore depositions. Where present its position is 15 to 25 feet above the Clarion coal. The following record, taken in the northwestern part of Section 31, shows the limestone with maximum development and its stratigraphic relations to other important beds:

	Ft.	In.
Ore, <i>Vanport</i>		7
Limestone, gray, good, <i>Vanport</i>	7	4
Shales, gray, parts covered.....	19	8
Coal blossom, <i>Clarion</i>	4	0
Clay, light, plastic.....	3	0
Sandstone, massive.....	9	0
Covered.....	9	0
Coal blossom, <i>Winters</i>	3	0

These small lenses of limestone are more or less isolated and usually less than 3 feet thick. Such deposits are found also just south of the old stack of Vinton Furnace in the central part of Section 31. The member was not observed along Elk Fork in sections 25 and 19 but appears on Flat Run in the southern part of Section 13. It lies just above drainage level at an elevation of about 680 feet. The bed is from 5 to 8 feet thick but is somewhat flinty in character. Its position here is nearly 290 feet below the Brush Creek limestone, which is the next marine deposit of this character in the locality.

Knox Township.—The only part of Knox Township in which the Vanport member is due above drainage is along Raccoon Creek in the northern part of Section 12. No limestone was observed on the horizon, the interval being taken by shale and sandstone, but the underlying Clarion coal is regularly present.

Clinton Township.—In Clinton Township the Vanport member is confined to that part of the area lying east of the old valley extending from Dundas to Hamden. Bordering this the limestone lies near the summit of the ridges but in the eastern part of the township it is present not far above drainage level. The bed has fair continuity and thickness in the central and southeastern parts but is wanting in the north-

eastern. It varies in character from a rather pure limestone, through cherty material to buhrstone, and in thickness from 1 to 10 feet.

Near Dundas the deposits are thin, flinty, and uncertain. On the ridge in the southeastern part of Section 9 and the southwestern part of Section 10, the member was formerly quarried for furnace flux. It is of good quality and 4 to 6 feet thick. The bed lies about 870 feet above tide. In Section 16 this limestone is generally present with a thickness between 1 and 5 feet and lies 1 to 5 feet above the Clarion coal and 15 to 20 feet below the Lower Kittanning member. Similar deposits were observed in the northern part of Section 15 but this limestone is generally absent in sections 1, 2, 11, 12, 13, and 14. Along the ridge north of Hamden Furnace in Section 21, are present local lenses of limestone which are much reduced by weathering, and which have an apparent thickness of 2 to 5 feet. Only scattered deposits were observed in sections 23 and 24 where the limestone is largely replaced by massive sandstone. The Vanport member appears with full thickness in sections 29 and 28, and in the west central part of Section 28 the following measurements were secured:

	Ft.	In.
Shale and clay.....	10	0
Ore, irregular, <i>Vanport</i>		2
Limestone, gray, good, <i>Vanport</i>	7	6
Shale, gray.....		4
Shale, dark, fissile.....	1	2
Coal, weathered.....	1	3
Clay, impure.....		6
Coal, good.....	1	2
Clay, with pyrite.....		1½
Coal, good.....		11½
Clay, siliceous.....	1	0

In this locality the bed varies in thickness from 2 to 10 feet and averages nearly 5 feet. It is of good quality, being a hard, dense, gray limestone low in siliceous matter. Formerly this stone was used at Hamden Furnace for fluxing purposes. The Vanport member is equally well developed where it appears near drainage level along the stream in the southeastern part of Section 27, along that in the southwestern part of Section 26, and along that in the southwestern part of Section 25.

Vinton Township.—In Vinton Township the Vanport limestone is present with fair continuity along Pierce Run and its tributaries in sections 34, 33, 27, 26, 21, 20, 25, and 19, and along Raccoon Creek in sections 10, 16, 9, 15, 14, and 13. In small areas its place is taken by sandstone. The usual thickness of the bed is about 5 feet and the maximum nearly 12 feet. The stone is of fair purity, only locally varying toward the flinty phase.

In the northwestern part of the township the Vanport member is generally wanting. It appears, however, with excellent thickness on the land of the New York Coal Company near Oreton in Section 33, where it was formerly quarried in a large way for the manufacture of Portland cement at Wellston. Measurements taken at that place are given below:

	Ft.	In.
Shale and shaly sandstone, gray.....	17	0
Coal, good.....	2	4
Clay, dark.....	} <i>Lower Kittanning</i>	9
Coal, good.....		4
Clay, plastic.....	7	0
Sandstone, argillaceous.....	20	0
Limestone, gray, good, <i>Vanport</i>	8	0
Shale, varies from 4 to 18 feet.....	10	0
Coal, rough.....	1	2
Clay, impure.....	} <i>Clarion</i>	8
Coal, good.....		0
Clay, pyritic.....		1
Coal, good.....		2

Along the stream in the southern part of Section 28, on the property of the Chicago-Oreton Company, small lenses of limestone 2 to 5 feet thick appear at the base of a massive sandstone that elsewhere replaces the Vanport member. In sections 26, 27, and 20 only isolated, bowldery masses of limestone remain to mark the horizon. On the Lincoln Furnace land in the western part of Section 25, the bed measures 6 feet 3 inches and is very free from flinty and ferruginous impurities. It is separated from the underlying Clarion coal by 2 feet 2 inches of black, carbonaceous shale, and the deposit lies about 710 feet above tide. The member, where exposed in the Campbell Tunnel of the Hocking Valley Railway in the southern part of Section 19, is made up of limestone 2 feet 6 inches to 4 feet 6 inches thick, and shaly flint 4 inches to 1 foot 8 inches. At the mine of the Syndicate Coal Company in the north central part of Section 19, the following record was secured:

	Ft.	In.
Sandstone, massive.....	30	0
Limestone, good, gray, <i>Vanport</i>	4	6
Shale, gray.....		4
Shale, black, carbonaceous.....	2	2
Coal, rough.....	1	4
Clay with thin coal bands.....	} <i>Clarion</i>	6
Coal, good.....		1
Clay with pyrite.....		1½
Coal, good.....		2
Clay, siliceous.....	2	0

Along Raccoon Creek in sections 13 and 14, the Vanport member

is uncertain in extent and variable in thickness. In these local deposits the thickness of limestone is from 1 to 6 feet. The quality of stone, however, is generally good. The member shows no improvement along Raccoon Creek in Section 15 and along Elk Fork in Section 16. In the vicinity of Arbaugh in Section 10, the stratum has fair development, being from 4 to 6 feet thick, but it passes below drainage just east of this place.

Wilkesville Township.—The Vanport member in Wilkesville Township appears at the surface only along Raccoon Creek from Section 24 southward to Section 20 and along the lower courses of its larger western tributaries, Rockcamp, Indiancamp, and Karr runs. The bed is moderately persistent, being replaced in only a few localities by sandstone. It varies in thickness from 1 to 8 feet but averages more than 5 feet. In composition and appearance it is very similar to that in the main field in Jackson and Lawrence counties. The position of the Vanport limestone is either directly or only a few feet at most above the Clarion coal.

On Rockcamp Run the Vanport member is above drainage from the forks of the stream in the western part of Section 30 to its mouth near Hawk in Section 24. The bed has good thickness, from 5 to 7 feet, but is locally very flinty in character. Its stratigraphic relations are shown in the following record taken near the mouth of the stream:

	Ft.	In.
Sandstone, massive.....	16	0
Limestone, part flinty, <i>Vanport</i>	5	6
Shale, black, fissile.....	2	2
Coal, rough.....	1	3
Coal, bony.....		3
Clay, impure.....		6
Coal, good.....	1	2
Clay with pyrite.....		1½
Coal, good.....	1	2
Clay, siliceous.....	1	0

Clarion

Along Raccoon Creek the Vanport member is locally replaced by sandstone north of Hawk but is very steady from this place southward to Clarion. The usual thickness is between 5 and 7 feet and the quality generally good. It has normal development also on Indiancamp Run in Section 28 and in the eastern part of Section 34. At the mine of the Minerton Coal Company in the central part of Section 27, the following rocks were exposed:

	Ft.	In.
Shale, gray.....	3	0
Limestone, gray, good, <i>Vanport</i>	7	6
Coal, rough.....	1	7
Clay, impure.....		6
Coal, good.....	1	1½
Clay with pyrite.....		1
Coal, good.....	1	3

Clarion

In this locality the Vanport limestone forms the roof of the Clarion coal, as it does in the main field in Jackson, Scioto, and Lawrence counties. It compares favorably also in regularity, thickness, and quality. It disappears below the bed of Raccoon Creek in the central part of Section 20.

Economic value

The Vanport or Ferriferous is the most important limestone stratum outcropping in Vinton County, far surpassing in value the Maxville, Lower Mercer, Upper Mercer, Putnam Hill, and Brush Creek members. The buhrstone on this horizon led to the early settlement of the region and to the development of the first industry, the making of millstones. This limestone was the chief source of flux for the six charcoal furnaces that formerly operated in the region. The overlying ore was also widely used in iron smelting. In importance the Ferriferous ore ranked next to the Upper Mercer. The Vanport limestone was extensively quarried for several years at Oreton for the manufacture of Portland cement at the Alma plant at Wellston. Aside from these it has been used also for road ballast, concrete stone, and agricultural lime. The material has thus supplied many needs and will probably be of more importance in the future.

The quantity of Vanport limestone available is large in Wilkesville, Vinton, and Clinton townships where the bed has excellent thickness and fair continuity over large areas. The supply is more limited, but is sufficient for all local needs in Elk, Madison, and Richland townships. Limestone from these deposits may be easily supplied to other parts of the county. The member varies from 1 to 12 feet in thickness, but averages, from 75 measurements taken in various parts of the field, 4 feet 7 inches. Where normally developed the bed is usually between 5 and 7 feet thick. The specific gravity of the stone is 2.66 and its weight per cubic foot more than 166 pounds. Where the bed is 6 feet thick and all available, the yield per acre is 21,693 tons. With drift mining and 60 per cent recovery, the quantity produced per acre is 13,016 tons.

The Vanport member is light to dark gray in color, which led to its designation in early reports as the "gray limestone." The principal coloring pigments are organic matter and ferrous carbonate. It is dense, breaking with a somewhat conchoidal fracture in any direction. Laminations are not especially prominent and bedding planes are generally absent in unweathered material. Through jointing the bed is regularly broken into large, rectangular blocks. The common impurities are clay matter and free silica as fine sand and as amorphous flint. Small crystals of pyrite are not uncommon and those of sphalerite and galena are occasionally observed. Cavities in the lime-

stone are frequently lined with either calcite or quartz of high purity. The upper part of the stratum is locally stained either pink or red with iron oxides carried down from the ore above by percolating water.

The general quality of the Vanport limestone in Vinton County is shown by the following analysis (D. J. Demorest, analyst):

	No. 1	No. 2
Silica, SiO_2	1.80	.69
Alumina, Al_2O_3	1.80	.78
Ferric oxide, Fe_2O_3	1.63	1.01
Lime, CaO	51.23	53.92
Magnesia, MgO	.64	.12
Titanic oxide, TiO_2	.02	trace
Phosphorus pentoxide, P_2O_5	.15	.12
Sulphur trioxide, SO_3	.79	.26
Loss at 105°C	1.50	.81

No. 1. Vanport limestone, Charles Dayton property, Section 30, Elk Township.

No. 2. Vanport limestone, Vinton Furnace land, Section 36, Elk Township.

Converting these components into the probable minerals present in the limestone, the results are as follows:

	No. 1	No. 2
Kaolinite or clay base, $\text{Al}_2\text{O}_3, 2\text{SiO}_2, 2\text{H}_2\text{O}$	3.84	1.49
Gibbsite, aluminum hydroxide, $\text{Al}_2\text{O}_3, 3\text{H}_2\text{O}$	.46	.29
Pyrite, iron sulphide, FeS_2	.60	.19
Siderite, ferrous carbonate, FeO.CO_2	1.79	1.27
Rutile, titanic oxide, TiO_2	.02	trace
Apatite, calcium phosphate, $3\text{CaO.P}_2\text{O}_5$	.33	.26
Calcite, calcium carbonate, CaO.CO_2	91.16	96.04
Magnesite, magnesium carbonate, MgO.CO_2	1.34	.25
Total.....	99.54	99.79

The above analyses are typical of the Vanport limestone elsewhere in Vinton County, especially in Richland, Clinton, Vinton, and Wilkesville townships. Where not contaminated with flint it is a fairly pure calcium carbonate with small quantities of admixed compounds chief of which are clay matter, ferrous salts, and magnesium carbonate. It is a satisfactory flux for metallurgical purposes and was used by all the charcoal furnaces that formerly operated in the county. Limestone quarried near Vinton Station was also shipped to furnaces in the Hocking Valley region.

The Vanport limestone is well fitted for the manufacture of Portland cement as attested by the fact that such a product was made for a number of years by the Alma Cement Company at Wellston from stone secured at Oretton in Vinton County. The cement was well within the limits both as to composition and as to physical properties. It was somewhat dark in color as shale was used with the limestone.

in the process of manufacture. By substituting clay, either Lower Kittanning or Clarion, a product much lighter in color could be made with little additional cost. The chief objection to using Vanport limestone for Portland cement is that large quantities are not available by surface quarry methods. It must be mined by drifting, which is expensive. In some areas of Vinton County, the roof of the limestone is a massive sandstone, safe and strong; elsewhere it is a tender shale, necessitating leaving a part of the limestone for support. Unless conditions are especially favorable, the manufacture of Portland cement from the Vanport limestone is not advised.

For many years this limestone has been successfully used for road metal not only in Vinton County but also in Jackson, Gallia, Scioto, and Lawrence. It is rated as "A" grade by the State Highway Department, thus comparing favorably with the best found elsewhere in Ohio. Tests of representative samples gave the following results: The Vanport limestone at Oretown shows abrasion 4.9 per cent, hardness 15.8, specific gravity 2.65, absorption 1.6 per cent, and toughness 5.5. Another sample from the mine of John Lawler at Minerton gave abrasion 3.6 per cent, hardness 17.3, specific gravity 2.68, absorption .6 per cent, and toughness 6.5. The quality of the limestone is similar throughout the entire area. Large quantities of material are available for road purposes in Richland, Elk, Madison, Vinton, Clinton, and Wilkesville townships, and from these deposits it may be cheaply transported to other parts of the county where such material is needed. In many places, especially in Elk, Richland, Madison, and Clinton townships, the deposits lie near the summits of the ridges and consequently have thin covering or at least for many feet back from the outcrop. Under such conditions the limestone may be stripped at low cost. Where drift mining is resorted to in Wilkesville Township, both limestone and Clarion coal may be taken from the same entry.

Where crushed and properly sized the Vanport limestone is an excellent aggregate for concrete as it is strong and durable. The pieces have sharp corners and edges and a rough, grainy surface to which the cement crystals can firmly attach. The stone is very free from partially decayed material of a friable, porous nature, and from that with a tendency to split along the bedding planes. In Vinton County, however, only small quantities of this limestone have been so used in the construction of building foundations, culverts, bridge piers, and abutments, silos, cellars, and walks.

The Vanport is not classed as a good building stone as it does not cut well. For rough foundation work, however, it can be used to good advantage and has been so employed in the central and the southern part of the county where such material is easily available.

The soil in Vinton County, except in small local areas along the outcrop of limestone beds, is decidedly acid in character as it is largely

derived from the decay of non-calcareous shales and sandstones of the Logan, Pottsville, and Allegheny formations. It would be much benefited by the regular application of lime, either raw or burned, which aids the growth of many plants and is especially effective with those of the leguminous types. Through this means soil fertility and increased yields are maintained.

The composition of the Vanport limestone is such that it is well fitted for agricultural purposes as the better grades of stone contain on the average about 93 per cent calcium carbonate, 1.5 per cent magnesium carbonate, and .35 per cent calcium phosphate, all of which have a sweetening power. Large quantities of limestone are available at low quarrying cost in many localities. Further, coal is at hand for power generation in crushing the material to a fine powder or for burning it to caustic lime. The cheapest and most effective method where only small quantities are needed is to burn the limestone in open piles using approximately 600 to 700 pounds of coal or about one-half cord of wood per ton of limestone. In well-built kilns the economy in fuel is much greater as one ton of coal will calcine nearly five tons of limestone and one cord of wood above three tons. The local demand for lime for soil sweetening is hardly such as to justify the erection of the permanent type of kiln, although such a product is much needed throughout the entire area. Portable crushers of the disintegrating type with a capacity of one to three tons per hour are very satisfactory for farm or neighborhood use. The product is sufficiently fine to neutralize soil acidity but acts less rapidly than caustic lime. At present the Vanport limestone is not regularly prepared for the trade at any place in Vinton County.

FERRIFEROUS ORE

Stratigraphy and extent

During the days of the charcoal furnaces in southern Ohio the Ferriferous ore was of great economic importance, leading directly to the establishment of the iron industry in the Hanging Rock district in 1826, and being the main reliance of more than 60 furnaces in this and the Hocking fields. With few exceptions the furnaces that succeeded best were those located along the line of outcrop of the Ferriferous ore. The Ferriferous was superior in yield of iron and in smelting qualities, was more reliable in thickness and in continuity, and made a better grade of foundry iron than the other ores in the region. The mean thickness of the ore was nearly 10 inches and the yield of iron about 40 per cent. The bed was extensively mined in Lawrence, Jackson, and Perry counties and, less widely, in Scioto, Gallia, Vinton, and Hocking; but north of this in central and eastern

Ohio the stratum so fails that it was little used for metallurgical purposes. In the southern counties the member was commonly called the "Limestone" ore on account of its position directly above the Vanport or Ferriferous limestone. In the Hocking Valley region it was designated the "Baird" ore as the deposits were especially important near Baird Furnace in Hocking County. The Ferriferous ore not only laid the foundation for the iron industry of southern Ohio, but was one of the chief factors in the development of the region.

In Vinton County the Ferriferous ore, although very widely distributed, occurs more in the form of irregular, isolated patches than as a sheet deposit. The member is locally present in Brown, Swan, Jackson, Richland, Elk, Madison, Vinton, Clinton, and Wilkesville townships. The deposits that were mined the most extensively were those in Elk and Clinton townships. The member varies in thickness from one inch to three feet or more but averages not more than ten inches. The mean of about twenty measurements made by the writer is five inches; but this is less than the true average as the thicker ore was stripped to deep cover and is now obscured by slumping and farming. Under deep cover the Ferriferous ore is a siderite of a blocky structure, of a gray or bluish-gray color, of a grainy texture, and with free silica as the chief impurity. The content of sulphur is low but that of phosphorus is sufficient to classify the ore as foundry grade. Along the outcrop the siderite has been altered by weathering agencies to a limonite of a yellowish or brownish color. It still retains the blocky structure due to a shell of firmly cemented ore inside of which are concentric layers of similar material and a core of soft, mellow ore. In this form it is known as kidney or block ore.

The Ferriferous ore was mined most largely by stripping along the outcrop as the unaltered carbonate under deep cover gave, in roasting, a ferrous silicate which was difficult to reduce in the short stacks of the charcoal furnaces. Where directly overlain by sandstone instead of shale, the siderite is altered to limonite under much deeper cover, as the circulation of ground waters is along the base of the sandstone stratum. Under such conditions and with a good thickness of ore, the bed was then mined by drifting. In Vinton County such a method was employed in only a few small areas. The common practice in stripping was that a foot of dirt could be profitably removed for an inch of ore. In general the depth of overburden removed was from 1 to 15 feet.

The Ferriferous ore is separated ordinarily from the underlying limestone by a thin stratum of shale. Locally, however, the two beds are firmly cemented, the ore gradating somewhat into the limestone. In places the upper part of the limestone stratum is so enriched by iron oxides that it has a pink or brown appearance. Under thin cover

and with advanced decay the cavities in the upper surface of the limestone and the wide spaces along the joint planes are filled with a soft clay-like ore formerly employed in a small way for pigment. It was too fine and dusty to be used in making charcoal iron.

Brown Township.—In Brown Township both the Ferriferous ore and the Vanport limestone are largely wanting, but on this general horizon small local deposits of ore are present in the shale overlying the Scrubgrass coal. The stratigraphic position of the bed is shown in the following record, taken along the road in the east central part of Section 19:

	Ft.	In.
Coal blossom, <i>Middle Kittanning</i>	3	0
Covered.....	12	0
Shale and covered.....	21	0
Coal blossom, <i>Lower Kittanning</i>	1	0
Clay and covered.....	10	0
Sandstone, massive, soft.....	8	0
Covered.....	10	0
Sandstone, massive, soft.....	13	4
Shale.....	1	0
Ore, nodular, <i>Ferriferous</i> horizon.....		4
Shale and shaly sandstone.....	7	4
Coal, <i>Scrubgrass</i>	1	+
Shale, black, fissile.....	6	10
Coal, <i>Clarion</i>	1	5
Clay, plastic.....	6	4

In this locality the ore varies from 2 to 6 inches in thickness but is unsteady in extent. The quality is poor as it is siliceous in character. It was not mined even for the charcoal furnaces.

In the shales between the Clarion and Scrubgrass coals irregular lenses and nodules of ore were observed at a few places. Such a deposit was well exposed in the cut of the Baltimore and Ohio Southwestern Railroad in the southwestern part of Section 8. The ore varies from 1 inch to 1 foot 2 inches in thickness and lies about 4 feet above the Clarion coal and 59 feet below the Lower Kittanning member. At this place the Scrubgrass coal is replaced by sandstone. The ore varies in kind from a siderite to a limonite and is siliceous in character. No fossils were observed either in the ore or in the associated shale. Directly above the Clarion coal a body of blackband ore about 2 feet 6 inches thick appears on the Timothy Clifford property near Hope Station, but the deposit is local.

Swan Township.—Only small patches of Ferriferous ore are present in Swan Township and these are confined most largely to the southeastern part. The ore was mined in a small way along the ridge in Section 10, on that east of Creola in the central part of Section 34, and on the knobs in the east central part of Section 31. At the latter

place the deposits are small but the bed is reported to be about 1 foot thick. Some flint is also present along with the ore. In Swan Township the Upper Mercer or Big Red Block ore was of far more importance and was extensively mined over a wide area.

Jackson Township.—Small deposits of Ferriferous ore and buhrstone are present on a few of the high knobs in Section 36, Jackson Township. The ore was little mined.

Richland Township.—The Ferriferous and Vanport members in Richland Township outcrop only along the summits of the high ridges in the eastern part. The deposits are small, being confined largely to sections 1, 13, and 24. The ore is frequently absent even where the limestone is present. It is also low grade and thin.

Elk Township.—In Elk Township the Ferriferous ore is widely, but on account of wants, erratically distributed over much of the area. The deposits most largely worked are those in sections 9, 10, 15, 16, 17, 22, 27, 30, 35, and 36. Locally the ore not only has good thickness but is above the average in purity.

In sections 9 and 10 the ore bodies are small and were mined to only shallow covering. The thickness reported is from 4 to 6 inches. The stratigraphic position of the member is shown in the following record made in the eastern part of Section 15:¹

	Ft.	In
Coal, <i>Middle Kittanning</i> , reported thickness.....	4	6
Covered.....	50	0
Coal, <i>Lower Kittanning</i> , reported thickness.....	3	6
Shale, gray.....	14	0
Ore, <i>Ferriferous</i>		6
Shale, gray, siliceous.....	1	3
Limestone and flint, <i>Vanport</i>	2	0
Clay.....		3
Coal blossom, <i>Clarion</i> .		

The Ferriferous ore was mined rather extensively by stripping along the ridges in Section 16. Here it rests on the buhrstone of the Vanport and in places is more or less mixed with this material. The deposits in Section 22 are described as follows:²

“The Ferriferous limestone is found with a fine development of limonite ore over it and a bed of coal reported 3 feet 4 inches thick a little below. The ore is quite irregular, but at one place attains a very unusual thickness. It is reported to range from a few inches to 9 feet, the reported average being 2 feet 6 inches to 3 feet. This is one of the most celebrated developments of ore in all southern Ohio. It has been mined by drifts, and the quantity taken from less than two acres is reported to be 10,880 tons. At one place the limestone and ore are both wanting. The strata in this locality follow:”

¹Geol. Surv. Ohio, Report of Progress, 1870, p. 107.

²Geol. Surv. Ohio, Report of Progress, 1870, pp. 108-9.

	Ft.	In.
Coal, <i>Lower Kittanning</i> .		
Sandstone and shale.....	35	0
Ore, limonite, <i>Ferriferous</i> , average.....	2	6
Limestone, <i>Vanport</i>	7	0
Clay.....		7
Coal, <i>Clarion</i>	3	4

Small quantities of ore were also mined at various places along the ridges in the southwestern part of the township in sections 28, 29, 30, 32, and 33. The association is ore and buhrstone, the latter replacing the Vanport limestone. The mining was all done by strip-ping. The best deposits are reported to be about 1 foot thick. In the eastern part of Section 26, the Ferriferous ore locally attained excellent thickness and was mined extensively. A section of the rocks follows:¹

	Ft.	In.
Coal blossom, <i>Lower Kittanning</i> .		
Sandstone and covered.....	33	0
Clay.....		5
Ore, <i>Ferriferous</i> , reported thickness.....	3	0
Limestone, <i>Vanport</i> , average.....	5	0
Clay.....	2	0
Coal, not opened, <i>Clarion</i> .		
Shale and sandstone.....	39	0
Coal, not opened, <i>Winters</i> .		
Shale.....	6	0
Ore, "gray kidney".....		4
Ore, "little fine block".....		10
Shale and sandstone.....	32	0
Coal, reported, <i>Brookville</i>	3	6
Sandstone and shale.....	36	0
Ore, "kidney".....	} <i>Upper Mercer</i>	2
Ore, "big red block".....		10

Samples of the Ferriferous ore were taken for testing. (For analyses, see page 274.) Small deposits of good ore were also worked in sections 27, 34, 35, and 36, but the thickness was at few places more than 1 foot and the average measurement much less.

Madison Township—Both the Ferriferous ore and Vanport limestone are wanting in the northern part of Madison Township except for stray lenses of ore and flint, neither of which are of economic value. They improve in continuity and development in the southern part of the township along Elk Fork and Flat Run. The best ore is in the vicinity of Vinton Furnace where it was mined in many places. The following record, taken in the northwestern part of Section 31, shows the stratigraphic features very well:

¹Geol. Surv. Ohio, Report of Progress, 1870, p. 111.

	Ft.	In.
Shale and covered.....	10	0
Ore, <i>Ferriferous</i>		7
Limestone, <i>Vanport</i>	7	4
Shale and covered.....	19	8
Coal blossom, <i>Clarion</i>	4	0
Clay, light, plastic.....	3	0
Sandstone, massive.....	9	0
Covered.....	9	0
Coal, old mine, <i>Winters</i>	3	0

Locally the ore thickens to 15 inches. In most places it lies directly above the Vanport limestone. Along Flat Run in Section 13 these members are present just above drainage level, but are uncertain in character and thickness. The ore was little mined.

Vinton Township.—In the main, deposits of Ferriferous ore in Vinton Township are confined to the valley of Pierce Run from Oreton to Radcliff and to that of Raccoon Creek from Arbaugh to Hawk. It is unsteady, in many places being replaced by sandstone. The ore is below normal in thickness but is of standard quality. The position of the member is as usual directly above the Vanport limestone but the ore is frequently wanting even where the limestone is present. The member was mined by stripping most largely in sections 10, 15, 16, 33, and 34.

Clinton Township.—The supply of ore for Hamden Furnace was drawn largely from the Ferriferous member in Clinton Township where the bed is found with fair regularity over the entire area east of the old valley that extends from Dundas to Hamden. It was mined most extensively in sections 3, 9, 13, 16, 21, 23, 25, 26, 27, 28, and 29. The deposits are variable in thickness, character, and association. The ore may be absent or may expand to as much as 3 feet. Through weathering it changes from a hard, gray siderite to a soft, brown limonite. It may be associated with limestone, with buhrstone, or in their absence with shale and sandstone.

The Ferriferous ore was mined in a number of places in the vicinity of Dundas in sections 3, 9, and 10. The thickness reported is about 1 foot with a maximum measurement in local swells of nearly 4 feet. The best developed deposits are those in the southern part of Section 9 where it was stripped to deep cover. In sections 1, 2, 11, and 12 the ore is very unsteady, in many places being replaced by sandstone. Likewise, for the same reason, the Vanport limestone and Clarion coal are absent from the section. Along the high ridge and its spurs in sections 13, 14, 15, 16, and 17, this ore is moderately persistent, has average thickness, 2 inches to 1 foot 4 inches, is underlain by Vanport limestone, and was mined at many places for the smelting of iron

in Hamden Furnace. In the southern part of the township in sections 25, 26, 27, 28, and 29, the conditions are similar. The stratigraphic features are normal throughout the entire area.

Wilkesville Township.—The only areas in which the Ferriferous ore appears at the surface in Wilkesville Township are along Racoon Creek from Hawk to Section 20, along Rockcamp Run in Section 30, along Indiancamp Run in Section 28, and along Karr Run in Section 27. In general the ore is poorly represented but the underlying limestone is well developed. The bed was little mined along Racoon Creek and only locally along its western tributaries.

Economic value

From 1830 to 1870, the period of greatest activity of the charcoal furnaces, the Ferriferous ore was the most important bed in southern Ohio, far outweighing in value any of the coals, clays, or limestones. Conditions have so changed that now (1925) it is not utilized at any place in the entire area. In Vinton County mining of the Ferriferous ore in a large way began with the erection of Eagle, Cincinnati, Vinton, Hamden, Hope, and Zaleski furnaces, between 1852 and 1858, and lasted during their periods of activity. It is of foundry grade, making a soft iron well suited for a wide variety of castings. In yield of iron and in economy of smelting this ore compares favorably to the more siliceous ores from the Great Lakes region. The general quality of the Ferriferous ore in Vinton County is shown by the following analyses made during the time the bed was being actively mined:

	No. 1	No. 2	No. 3	No. 4
Ignition loss.....	12.65	8.90	7.50	16.85
Ferric oxide, Fe_2O_3	65.65	60.86	79.37	64.36
Silica, SiO_2	17.26	22.16	6.64	8.56
Alumina, Al_2O_3	.05	.00	.00	1.00
Lime, CaO	.55	.12	2.95	1.99
Magnesia, MgO	1.28	.83	.56	2.68
Phosphorus pentoxide, P_2O_5	.215	2.524	.91	.384
Manganous oxide, MnO	1.40	3.95	1.75	1.45
Sulphur, S.....	.10	trace	.00	2.53
Totals	99.155	99.344	99.68	99.804
Metallic iron, Fe.....	45.95	42.60	55.56	45.05
Metallic phosphorus, P.....	.094	1.102	.397	.168
Metallic manganese, Mn.....	1.09	3.06	1.36	1.12
Specific gravity.....	2.709	2.307	3.333	

No. 1. Ferriferous ore, lower part of bed. Section 26, Elk Township. Geol. Surv. Ohio, Rep. of Progress, 1870, p. 111.

No. 2. Ferriferous ore, middle part of bed, same location. Idem.

No. 3. Ferriferous ore, upper part of bed, same location. Idem.

No. 4. Ferriferous ore, mixed siderite and limonite, same location. Idem, p. 112.

The Ferriferous ore in southern Ohio fluctuates, like other coal formation rocks, through rather wide limits in composition and character. The average of many samples of ore used for metallurgical purposes and gathered over a wide area gave the following data:

<i>Variation</i>				<i>Average</i>	
Iron, Fe.....	25.00	to 56.00	per cent	41.87	per cent
Phosphorus, P.....	.025	" 1.100	" "	.344	" "
Manganese, Mn.....	.05	" 3.00	" "	.91	" "
Lime, CaO.....	.05	" 15.00	" "	3.43	" "
Magnesia, MgO.....	.05	" 2.70	" "	1.13	" "
Silica, SiO ₂	1.60	" 32.00	" "	13.42	" "
Alumina, Al ₂ O ₃	.05	" 7.50	" "	1.77	" "
Sulphur, S.....	.01	" 2.75	" "	.46	" "
Ignition.....	5.00	" 30.00	" "	18.00	" "

The contents of lime and magnesia are usually higher in the siderite ore than in the limonite, for through weathering these components have been partially removed by the action of carbon dioxide in the circulating waters. In general this is also true of the silica as some desilication has taken place in the breaking down of the complex silicates. The quantity of sulphur is erratic in both the siderite and the limonite ores. In the siderite it is generally in the form of a sulphide, largely iron sulphide or pyrite, and in the limonite it is usually in that of a sulphate, such as gypsum or calcium sulphate. In the alteration the pyrite is first converted into ferrous sulphate and free sulphuric acid which readily combines with any bases present. Through solution and substitution a part of these sulphates may finally be precipitated as gypsum. Such material is locally abundant in ores lying near the surface, especially those that have been penetrated by plant roots. The range in phosphorus is generally much larger in the oxide ore than in the carbonate. Through solution and chemical changes a part of the bed may be impoverished in this component and another part enriched. The entire ore body may also be affected at the expense of associated strata. Such enrichment is thus more or less local either within the ore deposit or within a small area.

Before use in the charcoal furnaces the Ferriferous ore was calcined in order to remove hygroscopic and combined water, to convert the carbonates to oxides, to increase the porosity of the material, to increase the yield of the stack, and to save coke in the smelting operation. The treated ore was easily reduced by carbon monoxide in the upper part of the furnace, whereas the gray ore was more difficult to smelt. The fuel most used for calcination was wood, charcoal brands, and fine charcoal, as little deleterious materials such as sulphur and ash were thus added to the product. Coal was also used but with less favorable results. The ore was roasted in several ways, the most com-

mon of which were in piles built in the ground at the furnace, at the mine, or at the shipping point, and in kilns on the furnace yard.

The Ferriferous deposits in Vinton County are too thin to be worked at present for the ore alone as the "Lake" ores are far more economical. If mined as a secondary product in stripping the underlying limestone, the material has sufficient value to pay at least for its removal. Where the bed is 10 inches thick, the yield per acre is approximately 3,970 tons for the siderite and 3,290 tons for the limonite. In some localities Ferriferous ore, Vanport limestone, Clarion coal, and Clarion clay may be conveniently mined in this way. The overlying shale and Lower Kittanning clay are also of value for the manufacture of ceramic products. The combined section from the base of the Clarion clay to the top of the Lower Kittanning coal thus yields a variety of materials all useful for some purpose. The Ferriferous ore is not mined at present (1925) at any place in Vinton County and probably will never become important again for metallurgical use as the quantity is too small. The foundry iron made from it was of superior quality.

LOWER KITTANNING CLAY

Stratigraphy and extent

The Lower Kittanning clay underlying the Lower Kittanning or No. 5 coal is without question the most valuable and persistent clay stratum in Ohio as proved by its continued use for more than one hundred years in a wide variety of ceramic products. It occurs as a sheet deposit, with only slight interruptions, and outcrops in a southwesterly direction across the State from Columbiana and Mahoning counties on the north to Lawrence and Scioto counties on the south. Within this field the Lower Kittanning clay is utilized in a large or small way in nearly every county in which it appears at the surface. This great bed is an asset of value also far beyond the confines of Ohio, for extensive deposits are present to the eastward in western Pennsylvania, western Maryland, and northern West Virginia, and to the southward in eastern Kentucky. The member maintains an average thickness of about 8 feet throughout the entire field, at few places contracting to less than 4 feet or expanding to more than 15 feet. Further, for constancy in composition it is certainly the most reliable of all the clay members in the coal formations, which quality means much to the various ceramic industries using this material. In general the member yields only plastic clay but in local areas it also bears flint clay of good, heat-resisting quality. It is used in the manufacture of many kinds of ware but is especially well fitted for the production of sewer pipe, face brick, stoneware, yellow ware, fire proofing, and refractory ware.

The Lower Kittanning clay is a well recognized stratum over much of eastern Vinton County as it appears at the surface in large areas in Brown, Madison, Vinton, Clinton, and Wilkesville townships and in small areas in Swan, Elk, and Knox. The member is persistent except in a few localities where, by replacement, it gives way to sandstone. At other places it is much below the average in thickness. This impoverishment is either through loss of the upper portion of the bed by current action preceding the formation of the sandstone, or, more commonly, through lack of deposition of argillaceous sediments during the swamp period that closed eventually with the preservation of the vegetable matter as coal. In Vinton County, as elsewhere in Ohio, the thick deposits on this horizon in many places show a double structure, that is, they consist of two clay beds, each of which has its associated coal. The upper coal and clay, which are by far the most persistent, comprise the true Lower Kittanning, whereas the lower beds comprise the Lawrence.¹ Locally these clays coalesce, leaving little except a dark soot streak to mark the line of demarcation. In Vinton County the Lawrence coal as a definite bed is present in only a few places and the associated clay is very local in extent. On this account and their proximity to the Lower Kittanning, the two clays will be treated as a unit.

In Vinton County the position of the Lower Kittanning clay proper is directly below the Lower Kittanning coal which member is on the average 30 feet above the top of the Vanport limestone and 38 feet below the base of the Middle Kittanning coal. In this area, as elsewhere in Ohio, these intervals change considerably from place to place. The mean thickness of the clay stratum, from many measurements taken throughout the field, is 7 feet and the usual variation is between 4 and 10 feet. In the few places found the Lawrence coal with its associated clay is present about midway in the interval between the Vanport limestone and the Lower Kittanning coal. The thickness of this clay stratum is 2 to 5 feet and that of the coal 1 inch to 1 foot.

The clay on the Lower Kittanning horizon in Vinton County is nearly entirely plastic in kind, moderately uniform in grade, and nearly average in quality. It changes in character somewhat in different localities and in different parts of the bed. In general the lower portion of the stratum is decidedly siliceous, in many places gradating into a clay bonded sandstone. In this mica is also a common component. The upper portion of the bed is a rather pure, plastic clay of the coal formation type. The texture in both the siliceous and the aluminous grades is fine and uniform and the prevailing color, light gray. Just beneath the coal, however, a few inches of clay may be stained dark with carbonaceous pigments. Through weathering or grinding the

¹For a discussion of these members, see Geol. Surv. Ohio, Bull. 26, pp. 269-272.

Lower Kittanning clay develops a high bonding power thus fitting it for many useful purposes. In Vinton County it has been utilized only near Hamden at the Puritan plant of the McArthur Brick Company. The Lower Kittanning horizon, however, bears much good clay that will lead eventually to more ceramic development. Further, it also contains some coal of value.

Brown Township.—The Lower Kittanning clay is present above drainage along all the larger streams in Brown Township except on the headwaters of Sandy Run in the northeastern part. The dip of the bed to the southeast is nearly 30 feet to the mile or the descent above tide is from 920 feet near New Plymouth to 740 feet at Moonville. The stratum is a persistent sheet deposit which varies little in character. The usual measurement of the clay is between 5 and 8 feet and that of the overlying coal between 1 foot 3 inches and 2 feet 2 inches.

Along the road in the northwestern part of Section 18, the Lower Kittanning clay measures 9 feet 6 inches. The lower part of the bed is very siliceous but the upper part is about standard in quality. This clay lies 26 feet below the Middle Kittanning coal and 52 feet above the Clarion. Along the ridges elsewhere in the northwestern part of the township, the deposits are usually not so thick but are equally good, if not better in quality. The conditions are not far different on the main ridge and its spurs east of Raccoon Creek in the southwestern part. Some local thickening is evident simply by the addition of more of the siliceous clay to the basal portion of the stratum. The elevation of the member is 880 feet near the mouth of Twomile Run and 860 feet in the central part of Section 31. The quantity of clay is large and much of it is available by stripping. The overlying coal is not only thin, from 1 foot to 1 foot 6 inches, but is poor in quality. On Sandy Run the Lower Kittanning clay is above drainage from the mouth of the stream to the central part of Section 11. The following section, taken along the abandoned road about one-third mile east of Hope Furnace, shows the usual condition of the clay and its stratigraphic relations to other members:

	Ft.	In.
Clay and covered, <i>Bolivar</i>	7	0
Covered.....	27	0
Sandstone, massive, soft.....	43	6
Coal blossom, <i>Middle Kittanning</i>	1	0
Clay, impure.....	3	6
Shale, gray, siliceous.....	14	6
Shale, light, siliceous.....	1	0
Shale, gray.....	3	2
Shale, siliceous, ferruginous.....	1	0
Clay, plastic, dark, shaly.....	1	6
Coal smut and dark clay.....		2

} *Oak Hill*

	Ft.	In.
Clay, plastic, dark gray, impure.....	5	4
Clay, very ferruginous.....	1	0
Shale, gray.....	9	8
Coal, weathered, <i>Lower Kittanning</i>	1	5
Clay, plastic, argillaceous.....	3	6
Clay, plastic, siliceous.....	2	3
Sandstone, light, clay-bonded.....	1	6
Sandstone, shaly.....	2	0
Sandstone, massive, soft, micaceous.....	50	0
Covered.....	2	0
Shale, dark, carbonaceous.....	3	3
Coal, weathered, <i>Clarion</i>		7
Clay, plastic.....	2	10
Covered.....	5	4
Flood plain, elevation 720 feet.		

The maximum thickness of the Lower Kittanning clay on Sandy Run and its tributaries is about 10 feet and the average measurement nearly 6 feet. Aside from silica it is otherwise of fair purity, being very free from concretionary matter and pyrite crystals. It is well fitted for many kinds of ceramic products. In most of this area the bed lies at convenient height on the hills for ease in working and has good conditions for drift mining. The quantity available is large. Along Raccoon Creek near Hope Station the bed is uniform in thickness and character. On the hill south of the school house the following measurements were secured:

	Ft.	In.
Sandstone, massive, soft.....	28	0
Covered, old coal mine, <i>Middle Kittanning</i>	3	0
Covered.....	5	0
Shale and shaly sandstone.....	20	4
Clay shale.....		10
Clay, plastic, dark, carbonaceous.....		4
Clay, plastic, dark gray.....	1	4
Sandstone, shaly.....	1	2
Coal, weathered, <i>Lower Kittanning</i> , altitude 810 feet.....		8
Clay, plastic, light, good.....	5	4
Clay, plastic, siliceous, part ferruginous.....	3	0
Shale, gray, part siliceous.....	18	0
Sandstone, massive, coarse, soft.....	10	0
Covered.....	10	0
Shale, dark, carbonaceous.....	4	0
Coal, weathered, <i>Clarion</i>		7
Clay, plastic, argillaceous.....	7	4
Clay, plastic, siliceous.....	3	0
Shale and shaly sandstone.....	10	0

The Lower Kittanning clay shows similar development and quality along the stream in the south central part of Section 19 and along that in the southwestern part of Section 13. Locally lenses of very siliceous

material appear in the main body of the deposit. The strata on this general horizon are well exposed at the mouth of the tunnel of the Baltimore and Ohio Southwestern Railroad at Moonville. The section follows:

	Ft.	In.
Sandstone, part shaly.....	8	0
Shale, dark.....	1	8
Coal, <i>Lower Kittanning</i>	1	5
Clay, plastic, light, siliceous.....	2	0
Sandstone, soft, argillaceous.....	5	0
Clay, plastic, light, siliceous.....	7	0
Sandstone, irregular, coarse, massive.....	7	0

At this place the clay deposit has a double structure through the intervention of the argillaceous sandstone which averages about 5 feet in thickness. The lower bed of clay (7 feet) really belongs to the Lawrence coal, here absent, and not to the Lower Kittanning, and is of better quality but not as persistent as the upper stratum. In the southern part of Section 7 this bed gives way to sandstone, thus showing its pockety character; whereas the clay directly below the Lower Kittanning coal is regularly present and from 3 to 5 feet thick.

The quantity of Lower Kittanning clay in Brown Township is large and the quality sufficiently good for such products as face brick, fire proofing, flue lining, and related products. In most of the area conditions for mining this material are favorable as the bed lies at convenient height above drainage, is persistent, has ample thickness for entries, and has a fairly strong roof of gray shale. The Lower Kittanning clay along with the Clarion clay, which has exceptionally good properties, and with shales of various grades offers ceramic possibilities for a wide variety of useful products. Further, the region is well supplied with Middle Kittanning coal for manufacturing such wares, and has transportation facilities.

Swan Township.—In Swan Township the deposits of Lower Kittanning clay are confined to small areas along the main ridge east of the Hocking Valley Railway. Locally the deposits are well developed, but generally they are not above the average either in thickness or in purity. In places small bodies may be mined chiefly by stripping. The following record, taken on the knob in the east central part of Section 23, shows the main stratigraphic features:

	Ft.	In.
Coal blossom, <i>Middle Kittanning</i>	1	0
Clay, impure.....	1	0
Shale, siliceous, parts covered.....	20	4
Coal smut.....		2
Clay, dark, plastic.....	2	6
Shale, argillaceous.....	3	0
Clay, dark, plastic, impure.....	5	0

	Ft.	In.
Coal blossom, <i>Lower Kittanning</i> , altitude 968 feet.....	1	0
Clay, plastic, light, lower part siliceous, <i>Lower Kittanning</i>	13	0
Shale and covered.....	7	0
Sandstone, soft, light to yellow.....	8	0
Covered.....	11	0
Coal and covered, old mine, <i>Clarion</i>	4	0

The member has fair thickness, averaging about 6 feet along the ridges east of Raccoon Creek in the southeastern part of the township. Its position is 900 to 920 feet above tide. The overlying coal is everywhere thin and impure.

Elk Township.—Owing to the general rise of the rocks to the west, the deposits of Lower Kittanning clay in Elk Township are confined entirely to the high ridges and knobs in the eastern half. The elevation of the bed is about 920 feet in Section 2, 900 feet in Section 15, and 840 feet in Section 35. In many of the deposits the clay has good thickness and properties, making it an asset worthy of consideration. It has not been utilized, however, for ceramic purposes at any place within the area.

On the ridges in Section 1, from 5 to 8 feet of Lower Kittanning clay of average quality was observed at an elevation of approximately 925 feet. The deposits are not far different in sections 2, 11, and 12. The stratigraphic relation of the bed to other well known Allegheny members is shown in the following record taken along the road in the north central part of Section 14:

Allegheny formation	Ft.	In.
Sandstone and covered.....	8	0
Coal blossom, <i>Middle Kittanning</i>	2	0
Clay, plastic, impure.....	2	0
Shale and covered.....	45	6
Clay, plastic, with ore nodules, <i>Oak Hill</i>	4	0
Clay shale, dark.....	1	6
Shale, carbonaceous.....	1	0
Coal, weathered, <i>Lower Kittanning</i>	3	0
Clay, light, plastic, lower part quite siliceous, <i>Lower Kittanning</i> , altitude 915 feet.....	11	0
Covered.....	10	0
Sandstone, soft, light colored, <i>Kittanning</i>	22	0
Shale and covered.....	10	0
Coal blossom and dark clay, <i>Clarion</i>	1	0
Clay, plastic, light.....	4	0
Sandstone, light, clay-bonded.....	11	0
Sandstone, light, shaly.....	11	11
Shale, dark.....	2	0
Coal, bony.....		4
Shale with thin coal bands.....	1	0
Coal, shaly.....		5

} *Clarion*} *Winters*

	Ft.	In.
Shale.....		$\frac{1}{2}$
Coal, fair.....		$3\frac{1}{2}$
Clay, very impure.....	2	0
Shale, dark, horizon of <i>Zaleski</i> flint.....	1	0
Coal, <i>Ogan</i>		9
Clay, light, plastic.....	5	1
Coal, bony, local.....		4
Clay, light, siliceous.....	4	10
Shale, gray, upper part siliceous.....	17	4
Shale, fossiliferous.....	3	2
Limestone, fossiliferous, shaly.....		6
Coal.....	1	6
Clay, shaly.....		10
Coal, bony.....		4
Pottsville formation.		
Clay and covered.....	5	0

At this place the Lower Kittanning clay is above normal in thickness but the lower portion is decidedly siliceous. As a whole, however, the deposit is useful for the more common kinds of clay products. Locally in Section 15 the stratum is divided about midway by lenses of sandstone which vary from 1 to 5 feet in thickness. Such partings are decidedly objectionable in mining as only the clay above the sandstone could be removed with economy. Such modifications were also observed at a few places in sections 22, 23, and 26. Much good clay is present on this horizon in the southeastern part of the township east of the Baltimore and Ohio Southwestern Railroad and south of Elk Fork. The deposits expand from 5 to 10 feet or more and average at least 7 feet. In most of them the clay is highly plastic and very pure. Other conditions are also favorable for development.

Madison Township.—In Madison Township the Lower Kittanning clay is above drainage along Raccoon Creek in the northwestern part, along Wheelabout Creek well towards the headwaters of its tributaries in the central part, and along Elk Fork and Flat Run in the southern part. In general the deposits are not especially attractive as they are somewhat below the average in both thickness and quality. The overlying coal is also thin, adding little inducement for conjoint mining. Both clay and coal appear to be best developed in the vicinity of *Zaleski*, where the following record was measured along the abandoned road in the southwestern part of Section 30:

	Ft.	In.
Coal blossom, <i>Middle Kittanning</i>	1	0
Clay, light, plastic.....	1	0
Shale, gray, siliceous, part covered.....	16	0
Clay, light, with ore nodules at base, <i>Oak Hill</i>	3	0
Shale, gray, siliceous.....	16	0
Coal, weathered, <i>Lower Kittanning</i>	2	0
Clay, light, plastic, lower part siliceous.....	7	0
Sandstone, massive.....	34	0

Most of the exposures on Wheelabout Creek show from 5 to 8 feet of siliceous clay overlain with 1 foot to 1 foot 6 inches of bony coal. The elevation of the member is 773 feet in the central part of Section 23, 765 feet in the southwestern part of Section 16, and 780 feet about one mile east of Prattsville. In the valleys of Elk Fork and Flat Run both clay and coal are unsteady as they are locally, partially or completely replaced by sandstone. These members lie about 790 feet above tide at Vinton Furnace in Section 31 and 720 feet on Flat Run in the central part of Section 13.

Knox Township.—The dip of the rocks is such that the Lower Kittanning clay is entirely covered in Knox Township except along Raccoon Creek in sections 12, 6, and 5 in the northwestern part and along Tedroe Run in sections 10 and 4 in the west central part. In the few exposures observed the member is not above the average either in thickness or in quality. The overlying Lower and Middle Kittanning coals are also lacking in normal development, both being thin and uncertain.

Vinton Township.—Deposits representing Lower Kittanning time are present above drainage along all the larger streams in Vinton Township except along Raccoon Creek and its tributaries in the vicinity of Vales Mills in the northeastern part. In general the clay directly associated with the Lower Kittanning coal is thin and siliceous and that belonging to the Lawrence coal is absent, its place being taken by sandstone. Locally the overlying beds are also replaced by the same material. On this account the deposits are not attractive for ceramic work. Those of most value are found in the vicinity of Oreton.

On land of the New York Coal Company at Oreton, a sample was taken for testing. (For analysis see page 289.) The various strata measured at this place are shown in the record given below:

	Ft.	In.
Sandstone, shaly.....	4	0
Shale with ore balls.....	2	0
Clay, plastic, dark.....	1	0
Clay, plastic, light.....	3	8
Sandstone, light, coarse-grained.....	3	4
Shale.....	1	5
Sandstone, light, coarse-grained.....	3	0
Shale, and shaly sandstone, gray.....	17	0
Coal, good.....	2	4
Clay shale, dark.....		9
Coal, fair.....		4
Clay, dark, plastic, sampled.....		4
Clay, light, plastic, part siliceous, sampled.....	6	8
Sandstone, clay-bonded.....	20	0
Limestone, <i>Vanport</i>	8	0
Shale, dark to gray.....	10	0

		Ft.	In.
Coal, rough.....	} <i>Clarion</i>	1	2
Shale with bone coal layers.....			8
Coal, good.....		1	0
Shale with pyrite.....			1
Coal, good.....		1	2

In this locality the Lower Kittanning clay is moderately persistent but is subject to some diminution in thickness through replacement of the basal portion by sandstone. Where normally developed the bed has a mean thickness of about 7 feet. In kind it is siliceous, plastic clay much resembling that on the same horizon in Jackson and Lawrence counties. Its ceramic properties, both physical and chemical, are good. Further, in this locality the fuel for factory purposes is at hand as both the Lower Kittanning and the Clarion coals are present with minable thickness.

Near Radcliff the Lower Kittanning clay is largely replaced by a massive sandstone. The few lenses observed are thin and siliceous, far below the standard required for ceramic operations. The member is usually present but poorly developed along Raccoon Creek and Elk Fork. The elevation of the bed is about 680 feet on Alman Run in the northern part of Section 22; 670 feet at Arbaugh in Section 10; and 650 feet on Zinns Run in the central part of Section 7. The overlying coal is also thin and bony, only locally expanding to more than 1 foot. The Lower Kittanning clay in Vinton Township, except near Oreton, offers little to the ceramic worker.

Clinton Township.—In its extension westward from Vinton into Clinton Township the Lower Kittanning clay gains somewhat in persistence and uniformity but little in thickness and quality. The deposits are confined to the main ridges east of the old valley that extends from Dundas to Hamden. The elevation of the bed is 920 feet in the northern part of Section 16; 910 feet in the eastern part of Section 29; 795 feet in the central part of Section 1; and 785 in the northern part of Section 25. It is a plastic clay moderately high in silica and fluxing components. The main stratum, or that lying just below the Lower Kittanning coal, is ordinarily between 5 and 8 feet thick. The Lawrence clay, which is present at a few places only, lies several feet below the true Lower Kittanning, thus preventing mining the two beds conjunctively. The intervening material is shale and sandstone. These clays were formerly worked to some extent either alone or with shale for the manufacture of building brick by the Puritan Brick Company at the plant near old Hamden Furnace. The overlying Lower Kittanning coal is in places normally developed, being 3 feet or more thick, whereas the Clarion coal, found below the Vanport limestone, maintains an average of nearly 3 feet 6 inches of clean

fuel. A few sections will suffice to show the stratigraphic relations. Along the road in the central part of Section 16, the following measurements were obtained:

	Ft.	In.
Sandstone and covered.....	8	0
Shale, gray.....	7	0
Clay, dark, shaly, with ore nodules, <i>Oak Hill</i>	2	0
Shale, dark.....	1	4
Coal, rotten, <i>Lower Kittanning</i>	1	2
Clay, light, plastic, lower part siliceous, <i>Lower Kittanning</i> , altitude 915 feet.....	7	0
Shale and covered.....	9	0
Limestone, <i>Vanport</i> , not well exposed.		

Along this ridge the bed extends eastward, with no wants other than those due to erosion, through sections 15 and 14 to Section 13. Many of the exposures indicate clay of value. Locally the associated coal is 3 feet or more in thickness. Along the road in the east central part of Section 29, the following beds were exposed:

	Ft.	In.
Shale and shaly sandstone.....	16	0
Coal smut.....		3
Clay, plastic, dark to light.....	2	3
Clay, flint, light.....	1	0
Clay, plastic, light.....		6
Coal, weathered, <i>Lower Kittanning</i> , altitude 910 feet.....	3	0
Clay, plastic, light, <i>Lower Kittanning</i>	5	2
Sandstone, shaly.....	4	0
Shale, siliceous, gray.....	5	4
Coal blossom, <i>Lawrence</i>		8
Clay and covered, <i>Lawrence</i>	3	8
Limestone and flint, <i>Vanport</i>	2	0
Shale, dark.....	2	0
Coal blossom, <i>Clarion</i>	3	0
Clay and covered.....	5	0
Shale, gray, siliceous, parts ferruginous.....	12	9
Coal blossom, <i>Winters</i>		8
Clay, upper part dark and shaly.....	3	0
Clay, very siliceous.....	1	0
Shale, dark, carbonaceous, place of <i>Zaleski</i> flint.....		6
Coal, shaly, <i>Ogan</i>		5
Clay, impure.....	1	0
Shale, gray.....	8	6
Ore, weathered, shaly, local.....		10
Shale, gray.....	8	4
Shale, gray, fossiliferous, <i>Putnam Hill</i>	2	0
Coal, blocky, <i>Brookville</i>		5
Clay, lower part siliceous.....	5	0

At the mines of the Puritan plant of the McArthur Brick Company in the northeastern part of Section 28, the Lower Kittanning

clay proper is 6 feet thick but is not of high purity, as it is decidedly siliceous and somewhat ferruginous. The overlying coal is thin, the usual measurement being about 1 foot 6 inches. The Lawrence clay and coal are generally absent except for stray lenses interbedded in the shale above the Vanport limestone. Conditions are not far different along the main ridge and its spurs east of this in sections 27, 26, and 25.

The survey of Clinton Township thus shows that in the eastern half large quantities of medium grade, plastic clay are present on the Lower Kittanning horizon. Along some of the ridges, conditions are favorable for strip mining as the covering is thin and mostly shale. Where the overburden is thick, the usual method of drifting may be practiced and both clay and coal obtained from the same entry. The associated shales also have good properties for some grades of ware. The Hocking Valley and the Baltimore and Ohio Southwestern railroads offer shipping facilities to distant markets. The deposits are easily reached by short switches.

Wilkesville Township. — In Wilkesville Township the Lower Kittanning clay is present along the valley of Raccoon Creek from Section 24 southward to Section 14 and along the lower courses of its larger tributaries. The member is unsteady, locally giving way to sandstone. In a few localities the Lawrence clay and coal appear a few feet above the Vanport limestone and not far below the true Lower Kittanning stratum. In general the deposits of most value are confined to the southwestern part of the township. They have not been utilized for ceramic products.

Near the head of Rockcamp Run in Section 36, the Lower Kittanning clay, present approximately 720 feet above tide, is 3 to 8 feet thick. In places the lower portion of the stratum is more a clay-bonded sandstone than a true clay; and near Hawk all but about 3 feet of the member is replaced by argillaceous sandstone. This condition holds true also in the vicinity of Clarion and along Indiancamp Run, but near Minerton the member improves both in thickness and in quality. Further, the Lawrence beds are usually present in the interval between the Vanport limestone and the Lower Kittanning clay. These features are shown in the following record made along the road in the southwestern part of Section 27:

	Ft.	In.
Shale, gray.....	16	0
Shale, dark.....	3	9
Coal.....	1	8½
Shale.....	} <i>Lower Kittanning</i> , altitude 676 feet	
Coal.....		5½
Clay, light, plastic, good, <i>Lower Kittanning</i>	6	6
Sandstone, light, clay-bonded.....	4	0
Shale and shaly sandstone, gray.....	9	8

	Ft.	In.
Coal, somewhat shaly, <i>Lawrence</i>		10
Clay, impure.....		6
Shale, gray, siliceous.....	3	0
Covered.....	8	0
Limestone and covered, <i>Vanport</i>	5	0
Coal, weathered, <i>Clarion</i>	4	0
Clay, poorly exposed.		
Level of flood plain of Raccoon Creek.		

The Lower Kittanning clay where observed along Karr Run west of Minerton has normal development, good ceramic properties, and a thickness of 5 to 8 feet. In this locality the Lawrence clay is also present and lies close to the Vanport limestone, as shown in the following measurements taken at the mouth of an old coal mine in the central part of Section 27:

	Ft.	In.
Sandstone, massive.....	10	0
Coal, <i>Lawrence</i>		4
Clay, light, very siliceous.....	4	4
Clay with ore nodules.....		0
Limestone, <i>Vanport</i>	1	10
Coal and partings, <i>Clarion</i>	4	3

Along Raccoon Creek in Section 20, these beds are so modified by sandstone that they are thin and uncertain. The Lower Kittanning member is present at an elevation of 730 feet on Buffer Run, a tributary of Little Raccoon Creek, in the southwestern part of Section 33. Both clay and coal are well represented. On Greasy Run in the northwestern part of Section 6, the following beds were exposed:

	Ft.	In.
Sandstone, massive, soft.....	70	0
Coal, good.....	2	0
Clay, impure.....		2
Coal, blocky.....		3
Clay, plastic, light, good, <i>Lower Kittanning</i>	5	0
Sandstone, light, clay-bonded.....	5	0

In conclusion it may be stated that the deposits of Lower Kittanning clay of most importance in Wilkesville Township are those in the southwestern part. These may be reached at no great cost by the Hocking Valley Railway on Raccoon Creek or by the branch of the Baltimore and Ohio Southwestern Railroad on Little Raccoon Creek. Sufficient fuel for factory purposes is yet available in the Lower Kittanning and Clarion members.

Economic value

Next to the Clarion the Lower Kittanning is the most valuable clay stratum in Vinton County as it is widely distributed, has excellent

thickness in large areas, has a broad range of usefulness, and lies within the fields of minable coals. In addition to others it provides a wealth of material that should lead to a decided increase in the output of clay products in the region. Up to the present time (1925), however, the best clay on the horizon has not been utilized although such deposits are conveniently located for ease in mining and economy in plant operation. It is used with success both in Jackson, Scioto, and Lawrence counties to the south and in Hocking, Athens, and Perry counties to the north, where the quality of the clay is not greatly different.

In the Vinton County field the Lower Kittanning clay is entirely plastic in kind except for only occasional thin lenses in the upper part of the stratum tending toward the semi-flint variety. On weathering or working with water, it is reduced readily to a plastic mass that flows freely through the dies of the machine and has good body strength in the green state. Aside from clay matter the most abundant component in the Lower Kittanning is free silica which is present throughout the entire bed, although more concentrated in the lower portion, but which for many kinds of ware is advantageous instead of detrimental. Free silica tends to correct shrinkage, lamination, and warpage and in some cases produces a more desirable color. Muscovite in small scales is rather prominent in the siliceous clay on the Lower Kittanning horizon and is not uncommon in the more aluminous material. Pyrite is another ordinary component found in most deposits. These crystals of bisulphide of iron are usually small in size and highly diffused throughout the mass, thus causing no serious trouble other than in color. The deposits of Lower Kittanning clay in Vinton County are moderately free from concretionary matter of siderite, limonite, and calcite, the size of which is sufficiently large to be objectionable in the manufacturing processes. Locally, however, this clay contains such impurities in the form of fine oolites which, at the maturity of the body through firing, produce the iron-mottled effect much desired in some classes of ware. Along the outcrop of this member, as well as of other coal formation beds of like nature, the weathered clay is in many places contaminated with crystals of gypsum occurring singly or in clusters. They are secondary in origin and most liable to be found where the cover is so thin that the clay stratum has been penetrated by plant roots. Clay with much gypsum should be excluded as the calcium sulphate is an active fluxing and scumming agent. The Lower Kittanning clay always contains some carbonaceous matter in a highly diffused form and most concentrated in the few inches of clay lying directly below the associated coal. The quantity of such organic matter is so small that with fair practice in burning no damaging effects are evident in the finished product. In general the impurities in the Lower Kittanning clay in the Vinton County field are not often of such nature or in such quantity that they condemn the material for

wares ranging from high-grade face brick to sewer pipe. The quality of the better grades of this clay is shown by the following tests of a sample taken on the property of the New York Coal Company at Oretton:¹

<i>Chemical analysis</i>		<i>Percentage oxide ratio</i>			
Loss at 105° C.....	1.60	K ₂ O	.078	Al ₂ O ₃	1.00
Ignition loss.....	8.35	Na ₂ O	.013		
Silica, SiO ₂	58.25	CaO	.002		
Alumina, Al ₂ O ₃	24.90	MgO	.027		
Ferric oxide, Fe ₂ O ₃	2.11	FeO	.076		
Lime, CaO.....	.05	MnO	.000		
Magnesia, MgO.....	.67				
Titanic oxide, TiO ₂	1.63	RO	.196		
Phosphorus pentoxide, P ₂ O ₅	.02				
Sodium oxide, Na ₂ O.....	.31				
Potassium oxide, K ₂ O.....	1.94				
Manganous oxide, MnO.....	.01				
Sulphur, S.....	.35				
Total carbon, C.....	.30				
Inorganic carbon, C.....	.01				

Physical tests

Working properties: Plastic, smooth, works well in molding.

Tempering water..... 21.52 per cent.

Drying linear shrinkage..... 5.75 per cent.

Drying volume shrinkage..... 18.26 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 010	2.04	5.99	22.68	Light buff
Cone 03	4.12	11.85	19.52	Light buff
Cone 2	4.26	12.24	21.31	Medium buff
Cone 4	6.23	17.56	10.15	Medium buff
Cone 6	7.49	20.84	4.12	Gray buff
Cone 9	7.35	20.43	1.51	Gray buff speckled
Cone 12	5.46	15.51	0.99	Light gray speckled
Cone 15	0.27	0.80	1.04	Light gray speckled

Overburning temperature: Cone 12 (1,370° C. or 2,498° F.).

Best apparent burning range: Cones 4 to 9 (1,210° C. to 1,310° C. or 2,210° F. to 2,390° F.).

¹Geol. Surv. Ohio, Bull. 26, p. 289.

Total linear shrinkage at cone 9: 13.10 per cent.

Deformation temperature: Cone 29 (1,650° C. or 3,002° F.).

Possibilities: Intermediate heat duty refractories, face brick, sewer pipe, fire proofing.

The composition of the above sample, which is representative for that in many deposits within the area, is close to the standard for sewer pipe of the best grade. The clay matter, free silica, and basic compounds are well balanced. This clay is suitable also for face brick, fire proofing, and common fire brick. The working properties of the Lower Kittanning clay are always good. It grinds easily, screens well, and tempers readily. The plastic mass flows smoothly through the dies with little lamination or cracking. The green ware dries safely in any of the common types of driers and has sufficient strength to withstand factory handling. The burning behavior of this clay is also satisfactory as to range, shrinkage, and body structure. On the whole the Lower Kittanning clay ranks high for a large class of heavy duty clay products.

From more than thirty measurements the average thickness of clay on the Lower Kittanning horizon in large areas of Vinton County is nearly 7 feet. Counting 60 per cent available in drift mining, the yield per acre for such a bed is nearly 14,000 tons or enough to make approximately 4,000,000 building brick. Under the same conditions of mining the combined yield of the overlying Lower Kittanning coal with a mean thickness of 1 foot 10 inches and of the underlying Clarion member with a thickness of 3 feet 7 inches is approximately 5,850 tons, which is ample fuel for manufacturing the 7 feet of clay into ware. The same area thus provides coal and clay. If additional fuel is needed the Middle Kittanning, Winters, and Brookville members may be drawn upon to supply the deficiency.

In most of the field conditions for mining conjointly by drifting clay and fuel from the Lower Kittanning beds are very satisfactory, as the roof of the coal is shale of moderate strength or sandstone with massive structure. In local areas, however, the Oak Hill clay is present directly above the Lower Kittanning coal, in which case the roof is poor, necessitating leaving the coal for support or removing the clay also. For some kinds of ware the Oak Hill clay may be utilized as a mixture with the Lower Kittanning. The usual method practiced is first to mine the clay by shooting "off the solid," then to loosen the coal with a small charge of powder. Where beds outcrop near the ridge summits, as in parts of Clinton, Elk, and Swan townships, much clay may be secured by stripping by steam shovels or dray scrapers. The overlying shale in some localities may be utilized for common, vitrified red brick.

The Lower Kittanning clay in parts of Vinton County has much merit for buff and iron-mottled face brick, building and radial block, fire proofing, sewer pipe, and moderate heat duty refractory ware.

LOWER KITTANNING COAL

Stratigraphy and extent

The Lower Kittanning coal was first described in 1858 by H. D. Rogers of the First Pennsylvania Survey as the Kittanning coal from exposures near Kittanning in Armstrong County. It is one of the best known members of the Allegheny formation. The stratum is steady and widely distributed. It is present in large areas in western Pennsylvania, western Maryland, northern West Virginia, eastern and southern Ohio, and eastern Kentucky. It enters this State from Pennsylvania in Columbiana and Mahoning counties and passes into Kentucky in Lawrence and Scioto counties on the Ohio River. Also the bed is found at the surface to some extent in Jefferson, Stark, Carroll, Tuscarawas, Wayne, Holmes, Coshocton, Guernsey, Muskingum, Licking, Perry, Hocking, Athens, Vinton, Gallia, and Jackson counties. As a source of fuel the member is most valuable in Columbiana, Tuscarawas, Jackson, and Lawrence counties where the thickness of the bed is sufficient for drift mining in a large way and the quality of the coal near the standard for this State. This coal is mined in a small way for local needs throughout most of the remainder of the field. In importance the Lower Kittanning coal ranks below the Pittsburgh, Middle Kittanning, and Upper Freeport but above the Clarion, Brookville, Sharon, Quakertown, and Meigs Creek members. When, however, both coal and clay are considered, the economic value of the strata on this horizon far surpasses any other in the coal formations of Ohio.

In Vinton County the outcrop of the Lower Kittanning or No. 5 coal is confined to the central and eastern parts. It is present above drainage in Brown, eastern Swan, eastern Elk, Madison, northwestern Knox, Vinton, eastern Clinton, and western Wilkesville townships. In general the stratum is thin and of poor quality, being more comparable with that found to the north in Hocking, Athens, and Perry counties than with that to the south in Jackson and Lawrence counties. Further, in some localities the member is partially or completely replaced by sandstone. From more than seventy measurements taken throughout the field, the average thickness of the bed is 1 foot 10 inches and the maximum variation from 2 inches to 5 feet 1 inch. The most valuable deposits are confined largely to small areas in Clinton and Wilkesville townships. The normal position of the Lower Kittanning coal in Vinton County, considered from base to base of member, is 35 feet above the Vanport limestone, 45 feet above the Clarion coal, 10 feet

below the Oak Hill clay, and 38 feet below the Middle Kittanning coal, which measurements are not far different from what they are elsewhere in southern Ohio. These intervals are maintained with fair regularity except where massive sandstones intervene, in which case the contractions and expansions are locally abnormal.

In character the coal on this horizon in Vinton County is everywhere of the common bituminous type, in many places tending towards the shaly varieties and occasionally towards the bony cannels, and in general most of it is low grade. In the better developed deposits, those measuring 2 feet 6 inches or more, the member is divided by a thin layer of impure clay, into two coal benches, the lower stratum usually from 2 to 6 inches in thickness, the parting from 1 to 4 inches, and the upper stratum from 1 foot 5 inches to 3 feet 6 inches. In a few localities lenses of shaly coal and coaly shale appear just above the regular stratum. This material is correlative in character and position with the "nigger head," of the Jackson and Lawrence County fields.

Brown Township.—The Lower Kittanning coal is present above drainage in nearly all of Brown Township, lying close to the valley floors in the eastern part and near the ridge summits in the western part. In general the member is fairly persistent but poorly developed both as to thickness and as to quality. The deposit has provided little fuel even for local use.

Along the stream in the northwestern part of Section 18, the bed is present at an elevation of 820 feet and measures about 2 feet. The roof is either sandstone or Oak Hill clay. In Section 30 the deposits lie approximately 920 feet above tide and show no improvement in thickness. On the property of G. P. Drayer in the southwestern part of Section 23, the Lower Kittanning coal so expands locally that it was formerly mined for domestic use. From reports and drill records the bed is 5 feet or more thick and the fuel of good quality. At this place the altitude of this coal is 880 feet and its position 40 feet below the Middle Kittanning coal. On the headwaters of Sandy Run the member passes below cover in the central part of Section 11. In King Hollow in the south central part of Section 3, the following measurements are representative:

	Ft.	In.
Sandstone, shaly.....	5	0
Shale, dark.....		4
Coal, <i>Lower Kittanning</i> , altitude 720 feet.....		9
Clay, light, plastic.....	4	0

At this place the interval to the overlying Middle Kittanning coal is nearly 35 feet. In the vicinity of Hope Furnace the usual thickness of the Lower Kittanning coal is nearly 1 foot 6 inches and

in places it is of fair quality. The conditions are similar on the western tributaries of Sandy Run and also on Little Sandy Run. Along the ridge in the western part of Section 31, the Lower Kittanning coal, about 1 foot thick, is present at an elevation of 880 feet. It is separated from the Middle Kittanning coal by 21 feet of clay, shale, and sandstone, and from the Clarion member by 47 feet of similar material. The member shows no decided improvement in the vicinity of Hope Station.

In the cut of the Baltimore and Ohio Southwestern Railroad in the southwestern part of Section 8, the following beds were exposed:

	Ft.	In.
Sandstone, massive, soft.....	10	0
Shale, gray.....		8
Coal, <i>Lower Kittanning</i>	1	8
Clay, light, plastic.....	3	0
Sandstone, irregular, upper part argillaceous.....	8	0
Clay, plastic, irregular.....	2	0
Sandstone, massive, soft.....	34	0
Shale, dark.....	1	9
Ore, irregular, local.....		10
Shale, black, fissile.....	3	2
Coal, <i>Clarion</i>		11
Clay, dark.....	1	0
Clay, light, plastic.....	4	6
Level of railroad.		

The Lower Kittanning coal where well exposed in the railroad tunnel at Moonville in Section 7, is 1 foot 5 inches thick and of fair quality. In this locality the member is separated from the Middle Kittanning coal by an interval of 43 feet and from the Clarion bed by 44 feet. No improvement was apparent near Inghams in sections 2 and 1 where the stratum was observed at a few places.

Swan Township.—In Swan Township the deposits of Lower Kittanning coal are confined to the ridge summits and knobs east of the Hocking Valley Railway; and they are of small importance as they are generally thin and impure.

On the knobs in the eastern part of Section 12, the Lower Kittanning coal outcrops at an elevation of 980 feet. In Section 23 the horizon is marked by a thin bed of coal overlain by Oak Hill clay. The elevation of the Lower Kittanning coal is 968 feet and its position 43 feet above the Clarion coal and 33 below the Middle Kittanning. The only locality in Swan Township in which the Lower Kittanning coal has sufficient thickness for drift mining is along the ridge in the southeastern part of Section 27. The bed where worked on the Carney Johnson property has the following thickness:

	Ft.	In.
Shale, gray.....	4	0
Coal, bony.....	1	2
Clay shale		4
Coal, fair.....	1	8
Clay, impure.....		1
Coal, fair.....		5

Lower Kittanning, altitude 940 feet

The structure shown here is similar to that in Clinton Township, Vinton County; Milton Township, Jackson County; and Elizabeth Township, Lawrence County. It consists of two regular coal benches separated by impure clay and overlain by bony coal, usually called "nigger head." This coal bed lies about 40 feet above the Clarion coal. The member is present in an impoverished form east of Raccoon Creek in Section 36. Where observed the thickness is not more than 1 foot 3 inches.

Elk Township.—As a fuel asset the Lower Kittanning coal in Elk Township is of trifling importance for it is either thin or impure. The areas of outcrop are confined to the ridges lying east of the Hocking Valley Railway. The deposits have been worked at few places even in a small way.

The elevation of the member is 910 feet in Section 1 and nearly the same in Section 11. On the property of Jacob Morgan in the north-eastern part of Section 22, this coal has been mined in a small way. The thickness and structure of the bed are about normal but the quality is poor, as it is hard, bony, and bituminous, and tends towards an impure cannel. The measurements taken are given below:

	Ft.	In.
Shale, gray.....	5	0
Coal, bony.....		6
Shale, argillaceous.....		3
Coal, good.....	2	8
Shale, impure.....		1
Coal, good.....		4
Clay shale, sandstone, and covered.....	38	0
Shale, gray, with well preserved plant fossils.....	5	0
Clay shale, dark, with papery coal.....	1	3
Coal, poor.....		4
Clay shale.....		4
Coal, hard, bony.....	2	5
Clay shale.....		4
Coal, poor.....		6
Covered.....	6	0
Sandstone.....	25	0
Covered, <i>Vanport</i> limestone at intervals.....	6	0
Coal, rough.....	1	0
Clay, impure.....		6
Coal, good.....	1	7
Clay shale.....		1
Coal, good.....	1	1

Middle Kittanning

Lower Kittanning

Clarion

In the southeastern part of the township the Lower Kittanning coal at few places expands to more than 2 feet and averages not more than 1 foot 4 inches. In a few localities it is completely replaced by sandstone. The intervals to other well known beds are about normal for the county. No mines were observed.

Madison Township.—The stratigraphic and economic features of the Lower Kittanning coal in Madison Township are much the same as they are elsewhere in the northeastern part of Vinton County. The bed is moderately persistent but only locally expands so that it is mined in a small way. It is above drainage along the larger streams in the entire area.

West of Zaleski in sections 35 and 36 the bed is thin and in places it gives way to sandstone. East of Raccoon Creek the coal has been mined by drifting in the hollow south of the abandoned road in the central part of Section 30. It is reported to be nearly 3 feet thick and lies 38 feet below the Middle Kittanning coal and 69 feet above the Clarion coal. The stratum is 860 feet above tide. On the ridges south of Raccoon Creek in the vicinity of the high hill known as "the Pinnacle," the horizon bears little coal of value. Near the road forks in the central part of Section 23, the stratum was exposed in the stream bed. The record secured is given below:

	Ft.	In
Sandstone, massive.....	2	0
Shale, carbonaceous.....	1	0
Shale, gray.....	4	2
Coal, bony.....		5
Coal, good.....	1	9½
Clay, impure.....		
Coal, good.....		
Clay shale, sandstone, and covered	21	0
Sandstone, shaly.....	10	0
Shale, dark.....		5
Coal, good.....	1	2
Coal, bony.....		

Middle Kittanning

Lower Kittanning, altitude 773 feet

The Lower Kittanning coal, 1 foot 6 inches thick, where exposed in the southwestern part of Section 17, is separated from the Middle Kittanning member by 48 feet of shale and sandstone, and lies 770 feet above tide. The quality of the fuel is fair. The bed shows no improvement in sections 16 and 17. Along the valley one and one-half miles northeast of Prattsville, the Lower Kittanning coal was being mined by stripping on the property of John Love and the Middle Kittanning on that of Jacob Brush. The section at this place is given below:

	Ft.	In.
Sandstone, massive.....	12	0
Shale, dark.....	1	6
Coal, good, <i>Middle Kittanning</i>	1	7

	Ft.	In.
Shale, sandstone, and covered.....	26	0
Shale, gray.....	8	0
Shale, dark, with thin coal bands.....		3
Coal.....		1
Clay, impure.....	1	3
Coal, fair quality, <i>Lower Kittanning</i> , altitude 790 feet.....	1	4½

In this locality the Lower Kittanning member is reported to thicken to 1 foot 8 inches. On the property of the Vinton Iron Company at the head of Flat Run, about one and one-half miles southeast of Prattsville, the bed is mined by stripping for small supplies of household fuel. Where exposed the stratum is 1 foot 9 inches thick and very free from partings of shale and clay. It is overlain by black, carbonaceous shale. On Flat Run in Section 13 and along Elk Fork in sections 31, 25, and 19, the Lower Kittanning coal is in many places replaced by massive sandstone.

Knox Township.—In Knox Township the Lower Kittanning coal is below drainage except along Raccoon Creek in sections 12, 6, and 5, and along Tedroe Run in sections 10 and 4. In the few places observed the bed is thin but the fuel is of fair quality. The stratigraphic features are shown in the following record taken on the property of Miles Townsend in the southeastern part of Section 10:

	Ft.	In.
Sandstone, massive.		
Covered.....	10	0
Shale, black.....		10
Shale, gray.....	1	10
Coal, fair, <i>Middle Kittanning</i>	1	5
Shale, sandstone, and covered.....	24	0
Sandstone, massive.....	20	0
Coal, <i>Lower Kittanning</i> , altitude 720 feet.....	1	½
Clay, siliceous.....	1	0
Stream bed, Tedroe Run.		

Along Tedroe Run the Lower Kittanning coal is so modified by the overlying sandstone that it is occasionally reduced to a mere soot streak. The deposits are also of little value on Raccoon Creek, the maximum thickness observed being 1 foot 4 inches.

Vinton Township.—Although widely distributed in Vinton Township, the Lower Kittanning coal adds little to the fuel resources of the area as the bed is generally thin and impure. The outcrops are confined to the valleys of the main streams and to those of their larger tributaries. This coal has been mined in only a few places in the township for local use.

In the northwestern part of the township in sections 36, 35, and 34, the bed is unsteady through local replacement by sandstone, but

it appears in force at Oreton at which place it has been mined to a small extent. Where measured the lower bench of coal is 4 inches thick, the clay shale parting 9 inches, and the upper bench of coal 2 feet 4 inches. The coal is separated from the underlying Vanport limestone by 27 feet of clay and shale. South of this the bed again becomes thin and uncertain, at few places measuring more than 1 foot 8 inches. In the vicinity of Radcliff it locally gives way to sandstone. On the property of V. E. Cotterill on Zinns Run in the west central part of Section 7, the stratum outcrops along the bank of the stream at an elevation of 650 feet, and measures 1 foot 3 inches. In the southern part of Section 8 from 4 to 8 inches of coal was observed on the horizon. Little improvement was evident along Raccoon Creek in sections 14, 15, 9, 10, and 16. The bed thickens somewhat on Alman Run as shown by the following record taken in the northern part of Section 22 on the property of the Chicago-Oreton Company:

	Ft.	In.
Shale and sandstone.....	10	0
Coal, rough.....	1	7
Coal, shaly.....	} <i>Lower Kittanning</i> , altitude 680 feet	2
Coal, good.....		6
Shale, coaly.....		2
Clay, impure.....	1	0

The position of the bed is nearly 35 feet above the Clarion coal. The Lower Kittanning coal is poorly represented on Elk Fork in sections 24, 23, and 17.

Clinton Township.—In Vinton County the Lower Kittanning coal reaches its maximum development in the eastern half of Clinton Township where in local areas the deposits much resemble those in the main fields in Jackson and Lawrence counties. The bed has been mined in a small way for many years for local fuel, but the supply is far from exhaustion, as the larger bodies of coal are yet untouched. The associated clays are also of value. The Lower Kittanning coal is confined to that part of the township lying east of the old valley extending from Dundas to Hamden.

In sections 1, 2, and 3 the member is unsteady and generally thin. The elevation of the bed is 795 feet in the central part of Section 1 and 890 feet in that of Section 3. Where stripped for household use along the road in the northeastern part of Section 12, the stratum measures 1 foot 2 inches and lies 780 feet above tide. Along the Hocking Valley Railway in the northern part of Section 11, the Lower Kittanning coal was formerly mined for shipment, but the openings were so closed that no good measurements were obtained. The thickness reported is 3 feet to 3 feet 6 inches of clean coal broken about midway by a clay parting varying from 6 inches to 2 feet. Surface exposures

indicate that the member has fair development in parts of sections 10 and 9. Where observed in Section 16 the bed varies from 1 foot 2 inches to 1 foot 8 inches in thickness. Near the road in the north-eastern part of Section 15, the following record was obtained in a small wagon mine located on property of the Doney heirs:

	Ft.	In.
Shale and shaly sandstone.....	7	0
Coal blossom, <i>Middle Kittanning</i>	1	0
Clay, impure.....	2	0
Shale, siliceous.....	15	0
Clay and covered, <i>Oak Hill</i>	7	0
Sandstone, massive, soft.....	30	0
Coal, good.....	2	6
Clay, impure.....	} <i>Lower Kittanning</i> , altitude 875 feet	
Coal, good.....		
	1	6

The bed shows local contraction and expansion due to erosion preceding the deposition of the overlying sandstone. The coal is very free from bone partings and pyrite nodules. Its position is about 25 feet above the Vanport limestone and 30 feet above the Clarion coal. Along the road in the east central part of Section 14, the bed outcropping at an elevation of 860 feet is also mined in a small way by drifting. Where measured the lower bench of coal is $6\frac{1}{2}$ inches thick, the clay parting one-half inch, and the upper bench of coal 2 feet 7 inches. This is overlain by 5 inches of coaly shale and this in turn by about 30 feet of massive sandstone. The interval is approximately 39 feet to the *Middle Kittanning* coal, 22 feet to the *Clarion*, and 38 feet to the *Winters*. In Section 13 the *Lower Kittanning* coal is unsteady due to replacement of a part or all of the bed by sandstone. In the hollow in the south central part of Section 24, this coal has been mined both by stripping and by drifting. The record secured follows:

	Ft.	In.
Shale and covered.....	10	0
Coal, poorly exposed, <i>Middle Kittanning</i>	1	0
Shale, sandstone, and covered.....	32	0
Shale with thin coal bands.....	5	0
Coal, shaly.....	} <i>Lower Kittanning</i> , altitude 785 feet	4
Coal, good.....		4
Clay, impure.....		3
Coal, good.....		3

In sections 23 and 22 the bed is persistent but not everywhere well developed. Formerly it was mined along the ridge in the northern part of Section 21 at which place its elevation is about 900 feet and its position nearly 25 feet above the Vanport limestone. In Section 29 the deposits are confined to a few knobs in the east central part and in Section 28 to the main ridges in the southern and eastern parts.

In the latter area the bed has been mined by drifting at many places, supplying fuel for household use and for brick manufacture at the Puritan plant of the McArthur Brick Company. At the drift mine of Webb Carr in the southwestern part of Section 28, the following beds were exposed:

	Ft.	In.
Shale and covered.....	4	0
Coal blossom, <i>Middle Kittanning</i>	2	0
Shale, sandstone, and covered.....	38	0
Shale, siliceous.....	3	0
Coal, bony.....	1	2
Coal, good.....	3	9
Clay and bone coal..		3
Coal and bone shale..		2
Clay and covered.....	15	0
Limestone, <i>Vanport</i>	2	0

In this locality the position of the Lower Kittanning coal varies from 15 to 30 feet above the Vanport limestone. The outcrop exposures along the high ridge in the eastern part of Section 28 indicate that here the bed is generally thin, from 1 foot 4 inches to 2 feet 6 inches. In the hollow in the southeastern part of Section 27, both the Lower Kittanning and Clarion members were formerly worked for shipment. The structure and stratigraphic relations of the beds are shown in the record given below:

	Ft.	In.
Sandstone, soft.....	5	0
Shale, black.....	6	0
Coal, good.....	2	0
Clay, impure.....		$\frac{1}{2}$
Coal, good.....		6
Clay, siliceous.....	2	6
Covered.....	30	0
Shale, black, bony.....	3	0
Coal, rough.....	1	0
Coal, bony.....		4
Clay, impure.....		8
Coal, good.....	1	3
Clay with pyrite.....		2
Coal, good.....	1	3

Along the valley in the southeastern part of Section 26 and the southwestern part of Section 25, both coal members have been mined in a large way. The Lower Kittanning stratum at an elevation of about 810 feet is very regular in structure and thickness in this locality. It is regularly divided in two coal benches of 3 inches and 2 feet 5 inches respectively separated by a clay parting of 2 to 4 inches. The coal is of good quality, being bright and clean. Its position is 39 feet below the Middle Kittanning coal and 25 feet above the Vanport limestone.

Wilkesville Township.—The Lower Kittanning coal is present above drainage along the larger streams in the western half of Wilkesville Township. Its altitude is 720 feet on Rockcamp Run in the northern part of Section 36, 680 feet along Raccoon Creek in the northern part of Section 24, 710 feet on Greasy Run in the northwestern part of Section 6, and 630 feet on Raccoon Creek in the southwestern part of Section 20. In general the bed is not well developed, averaging less than 2 feet in thickness and at few places expanding above 3 feet. In restricted areas the coal gives way to sandstone. These deposits have been mined only in a small way for household fuel.

Along Raccoon Creek in the vicinity of Hawk, the Lower Kittanning coal is thin and shaly. A small area of good coal is present on Indiancamp Run east of Clarion where it has been mined both by drifting and by stripping. On a tributary of this stream in the southern part of Section 29, the following measurements were secured on the property of C. K. Davis:

	Ft.	In.
Shale and covered.....	16	0
Coal blossom, <i>Middle Kittanning</i>	1	0
Clay and shale.....	3	0
Sandstone, shaly.....	5	0
Shale, siliceous.....	7	0
Shale and covered.....	20	0
Sandstone, shaly.....	8	0
Shale, gray.....		11
Shale, soft.....		3
Coal, bony.....	1	6
Clay, impure.....		2
Coal, good.....	1	8
Clay, impure.....		2
Coal, good.....		5
Clay and covered.....	16	0
Limestone, <i>Vanport</i>	7	0
Shale, dark, fissile.....	1	2
Coal, rough.....	1	6
Clay with coal bands.....		7
Coal, good.....	1	2
Clay with pyrite.....		1
Coal, good.....	1	5
Coal, bony.....		1

Lower Kittanning

Clarion

At this place the position of the Lower Kittanning coal is 138 feet below the Upper Freeport coal, 178 feet below the Mason coal in the Conemaugh formation, and 223 feet below the Brush Creek limestone. On Indiancamp Run in the north central part of Section 34, the member was well exposed in the small mine on the property of Hiram Dorton. The measurements follow:

	Ft.	In.
Shale, gray.....	3	0
Coal, somewhat bony.....	2	8
Coal, good.....		0
Clay shale.....		2
Coal, good.....		4

Lower Kittanning, altitude 740 feet

In this vicinity the bed is reported to expand to as much as 3 feet 10 inches in thickness which is comparable to that on Rich Run in Milton Township, Jackson County, where it has been extensively mined for shipment. Near Clarion in sections 28 and 22 the bed is of little value, usually being less than 1 foot 8 inches thick. It improves somewhat near Minerton in Section 27. Where exposed along the road east of the village the lower bench of coal measures 5½ inches, the parting 1 inch, and the upper bench of coal 1 foot 8½ inches. The quality of the fuel is fair. The altitude of the bed is 676 feet and its position 30 feet above the Vanport limestone. On Karr Run in the southwestern part of Section 33, the upper bench of coal, 1 foot 11 inches thick, was exposed in the stream bed at an altitude of 710 feet. The member is above drainage on Greasy Run, a tributary of Little Raccoon Creek, in the southwestern part of Section 32 and the northwestern part of Section 6. Where measured it has the following thickness and structure:

	Ft.	In.
Sandstone, massive, soft.....	70	0
Coal, good.....	2	0
Clay, impure.....		2
Coal, good.....		3
Clay, plastic, light.....		0

Lower Kittanning

Along Raccoon Creek in Section 20, the Lower Kittanning coal is much impoverished through lack of deposition and through loss by erosion preceding the deposition of the overlying sandstone. In places the horizon is marked only by "finger" coal in the sandstone or by thin lenses appearing along the line of disconformity. This condition is well shown in the cut of the Hocking Valley Railway in the southwestern part of Section 20. The Lower Kittanning coal is reported to appear in the bed of Raccoon Creek in the extreme northern part of the oxbow in the central part of Section 14 where small quantities were obtained by stripping. As given, the thickness of the bed is from 2 feet 6 inches to 3 feet. Little is known regarding this member under deep cover in Wilkesville Township but from conditions along Raccoon Creek the prospects for large bodies of thick coal are not encouraging.

Economic value

The areas of Lower Kittanning coal in Vinton County with the necessary thickness for mining in a large way are small, more in the

form of isolated patches, which border on the north the main fields in Jackson and Lawrence counties. On this account the bed is not important for a stable mining industry. Its value lies chiefly in that it is capable of furnishing for many years small supplies of fuel for household consumption and factory purposes, and in that it is associated with a large and persistent group of clays and shales, useful for the manufacture of a wide variety of ceramic products.

In this region the Lower Kittanning coal varies considerably in quality from place to place throughout the field. It changes from a soft, bituminous coal, fairly free from deleterious matter, to a hard, cannel-like fuel, decidedly shaly in character. In general the purity of the coal in the thicker deposits is greater than it is in the thinner ones. The Lower Kittanning is a high volatile, free-burning fuel, moderately low in sulphur and ash. On the average it contains about 8 per cent moisture, 36 per cent volatile matter, 48 per cent fixed carbon, and 8 per cent ash. The content of sulphur, present mainly in the coal in the form of pyrite, is approximately 2.7 per cent. The ash clinkers only at high temperatures as it is clay-like in character. The heating value of this fuel is from 6,600 to 6,800 calories or 11,880 to 12,240 B. t. u.

The Lower Kittanning coal is well liked for domestic purposes as it ignites readily, burns freely, produces little soot, and leaves a light powdery ash. Next to the Quakertown it is the best coal for household purposes in Vinton County. It is very satisfactory also for burning ceramic products as the long flame produced gives a good finish to the surface of the ware and carries the heat down to the bottom of the kilns. Further, although its heating value is only moderate, this fuel burns so freely that high temperatures may be maintained with little difficulty. For steam generation the Lower Kittanning coal is well recommended by those using the common kinds of grates and also by those employing the mechanical types of stokers. The clay-like nature of the ash is such that only small clinkers are formed even at high temperatures. On the whole the Lower Kittanning is a very efficient general purpose fuel.

The stratum has fair mining conditions for in most of the field the roof is gray shale, above the average in strength, or a massive sandstone. In a few localities, however, the Oak Hill clay lies on or close above the coal, in which case drift mining is dangerous and costly. As the floor of the coal is everywhere a plastic clay, some trouble is occasioned in wet mines by the sinking of posts and tracks and by "squeezes" on the pillows from the weight of the overburden. In general the yield of fuel should exceed 70 per cent.

HAMDEN MEMBER

Stratigraphy and extent

The Hamden is one of the unsteady and variable members in the coal formations of Ohio. It may be represented by a regularly bedded limestone, by nodular limestone, by calcareous shale, by iron ore, or by some combination of these. It occurs more in the form of lenses of small or medium size than in that of a sheet of wide extent. The areal range of the member as now known is from Beaver County, Pennsylvania, southwestward to Jackson County, Ohio. Future work may extend this both to the east and to the south. In this State the material in some form on the Hamden horizon appears in local areas in Columbiana, Mahoning, Stark, Carroll, Tuscarawas, Coshoc-ton, Muskingum, Perry, Hocking, Athens, and Vinton counties.

The limestone and calcareous shale are of marine origin as they bear an abundant fauna of that character, but the method of formation of the iron ore is not so clearly indicated. Most of it appears to have been laid down in shallow arms of the sea as a ferruginous limestone which, during the long period since the Alleghenian rocks were elevated into a land mass, has been so altered by ground waters, especially near the outcrop, that the rock has lost most of its calcium carbonate and gained in iron oxide. Such ore and in many cases the associated shale are sparingly fossiliferous with either salt or brackish water types. In the southern extension of the field in Vinton and Jackson counties, the few isolated bodies of Hamden ore appear to be of true bog or swamp origin. In the unaltered ore the iron is mainly in the form of ferrous carbonate or siderite and in the weathered material along the outcrop and under shallow cover it occurs largely as ferric hydroxide or limonite. The phosphorus is held both as calcium phosphate and ferric phosphate, but largely as the latter.

The Hamden member lies either directly on or only a few feet above the Lower Kittanning coal and just below or in many places within the body of the Oak Hill clay. Where it forms the roof of the coal, the material is usually shale with more or less nodular limestone, both highly fossiliferous. In a few localities such deposits consist of bowldery limestone in irregular, lenticular layers, separated by shale partings. Where bedded within the clay, the horizon is less definitely marked, the most common representative being concretions and ill-shaped bodies of ferruginous limestone and impure iron ore.

In Vinton County the Hamden member is poorly developed except in a small area near Hamden Furnace in Clinton Township where it occurs as an iron ore, rather lean in iron but rich in phosphorus. In the old charcoal furnace at this place the ore was tried but soon con-

demned as the iron made from it was hard and brittle. Later a few thousand tons were shipped to Columbus and Buffalo to mix with lake ores in order to increase the phosphorus content of foundry iron. The ore bodies are present in the form of irregular lenses of small extent, but with excellent thickness. The following record, taken at a mine on land of the Puritan Brick Company in Section 16, shows the main stratigraphic features:

	Ft.	In.
Shale, weathered.....	3	0
Coal, <i>Middle Kittanning</i>		6
Clay, impure.....	1	0
Shales and sandstones.....	10	0
Sandstone, shaly, ferruginous.....	1	11
Ore, irregular, kidney, 1 to 5 inches, <i>Red Kidney</i>		2
Shale, gray.....	1	7
Coal, shaly.....		1
Clay, dark, part flinty, with scattered ore nodules, <i>Oak Hill</i> ...	2	6
Ore, <i>Hamden</i>	9	0
Shale, reported thickness.....	2	0
Coal, <i>Lower Kittanning</i> , reported thickness.....	1	6

In this deposit the ore varies from 1 to 12 feet in thickness but measures usually between 2 and 4 feet. Its position is at the base of the Oak Hill clay and from 2 to 3 feet above the Lower Kittanning coal. Both the upper and lower surfaces of the ore are irregular in outline. The material varies from red to brown to gray, depending on the state of oxidation. It was mined entirely by stripping. Elsewhere in Vinton County the Hamden member is of no value economically and has little interest stratigraphically. In a few places in Elk, Madison, and Brown townships, the horizon is marked but poorly by scattered nodules of impure ore at the base of the Oak Hill clay. Neither the limestone nor the shaly phase was observed at any place within this area.

Economic value

Although the quantity yet available is small, the Hamden ore is of some interest commercially, more for its content of phosphorus than that of iron. The element phosphorus is very effective in increasing the fluidity of molten iron and in preventing the oxidation of other metals present. It thus assists in the production of sound castings in foundry work. It is combined with the iron as the phosphide, FeP. In the Hamden ore the phosphorus varies from 2 to 12 per cent but averages between 4 and 5 per cent. In general the ore richest in phosphorus is that in the lower part of the deposit. The fluctuation in iron in the material is from 25 to 55 per cent, but the average is approximately 33 per cent. This ore carries also nearly one-half

the bases, lime and magnesia, needed for fluxing the silica and alumina present. Through the kindness of Mr. J. H. Frantz of the American Rolling Mill Company, Columbus, Ohio, the average analysis of 29 cars of ore is given below: (Percy Daines, analyst)

	Dry at 212° F.	Natural
Iron, Fe.....	33.09	28.87
Silica, SiO ₂	9.20	8.03
Phosphorus, P.....	4.78	4.17
Manganese, Mn.....	.85	.74
Alumina, Al ₂ O ₃	8.37	7.30
Lime, CaO.....	9.75	8.51
Magnesia, MgO.....	.90	.79
Ignition loss.....	11.60	10.12
Moisture.....	.....	12.75

Under normal furnace practice the iron resulting from the smelting of Hamden ore alone would have the following approximate composition:

Carbon, C.....	4.00
Silicon, Si.....	2.00
Iron, Fe.....	81.21
Phosphorus, P.....	11.73
Manganese, Mn.....	1.06
Total.....	100.00

The product is a ferro-phosphide iron, hard and brittle, and silvery in appearance. Such an iron is only slightly inferior to that now considered standard and used widely in foundry work. The Hamden ore has thus a special field of usefulness in a region where such material is frequently needed and not widely distributed.

OAK HILL CLAY

Stratigraphy and extent

The Oak Hill clay, named for deposits which have been mined in a large way since 1873 at Oak Hill in Jackson County, has a known areal range from the Beaver Valley in western Pennsylvania southwestward to the Ohio River in southern Ohio. The member, however, is far from persistent as it is subject to many wants throughout the entire field. These are due more to lack of deposition than to other causes. The Oak Hill clay was laid down in a coal formation swamp of wide extent with vegetable matter and acid waters as the chemical agencies that purified the shale sediments there entering. The swamp as such was not continuous but consisted of many bogs

which were separated by land, bars, and shoals, and in which alone conditions were favorable for deposition of the clay-forming sediments. Likewise the Oak Hill clay varies greatly in character from place to place, the most common representative being plastic clay of low to medium quality. Along with this in some localities is flint clay in irregular masses, lenses, and sheets. The quality of this material is good or poor, depending on the quantity of concretionary matter and diffused bases that may be present.

The Oak Hill clay is present in the interval between the Lower Kittanning and the Middle Kittanning coal, lying normally much closer to the former than to the latter. The average position of the bed is 7 feet above the top of the Lower Kittanning coal and 20 feet below the base of the Middle Kittanning; but these relations are variable. The Oak Hill clay may be present anywhere from 1 to 25 feet above the Lower Kittanning coal, may lie directly on the coal, or in the absence of this stratum, may rest with no sharp line of demarcation on the Lower Kittanning clay. All these conditions are found in the Ohio field and often in a rather small area. The Oak Hill clay has an average thickness of nearly 4 feet with a minimum and maximum of 1 and 20 feet respectively. In this State the member is of most value in Jackson County. In Vinton County the Oak Hill clay is present, but with many wants, due to lack of deposition and to replacement by sandstone, in the eastern part in Brown, eastern Swan, eastern Elk, Madison, Knox, Vinton, eastern Clinton, and western Wilkesville townships. The mean thickness of the stratum is nearly 4 feet, but the variation observed is from 1 foot 8 inches to 8 feet 6 inches. On the average the bed is separated from the Lower Kittanning coal by 8 feet of shale and sandstone and from the Middle Kittanning by 24 feet of similar materials. The variation of the interval to the Lower Kittanning coal is from 1 to 25 feet. In the Vinton County field the Oak Hill member is commonly a low-grade plastic clay, very siliceous, and in many places ferruginous in character. Flint clay is present only locally on the horizon. Most of it is poor in quality owing to the presence of concretionary matter and crystalline pyrite. These clays have not been directly employed for the manufacture of ceramic products at any place in Vinton County.

Like the other clay beds in the coal formations, the Oak Hill clay marks a horizon on which coal should also appear, as both materials represent swamp deposition but were laid down under somewhat different conditions. Coal and clay are directly related as to place and to time of sedimentation but differ in the kind of matter preserved and in some of the chemical and physical agencies operative. The Oak Hill clay is overlain by coal although the bed is commonly only a mere soot streak and at most only a thin layer of bony coal.

This impoverished stratum in southern Ohio appears to be correlative with the No. 5a or Strasburg coal with fair development in northern Tuscarawas and southern Stark counties. In the Strasburg field the bed varies from a few inches to more than 2 feet in thickness and in general lies about midway in the interval between the Lower Kittanning and the Middle Kittanning coals. In this bulletin the coal associated with the Oak Hill clay in southern Ohio is considered in a broad sense as Strasburg. The Oak Hill deposits in many places show a composite structure, that is, they are made up of two, three, or even four clay strata divided by coaly partings. Such features are also present in central and eastern Ohio and in western Pennsylvania.

Brown Township.—The Oak Hill clay is locally present along all the larger streams in Brown Township. It has little merit, however, for the manufacture of ceramic products as it is poor in quality, variable in character, and uncertain in extent. In this area flint clay is at few places associated with the plastic. The deposits vary from 1 to 7 feet in thickness but average only about 4 feet. The overlying coal is seldom more than a mere soot streak.

The following record, taken on the headwaters of Twomile Run in the northwestern part of Section 18, has features of interest:

	Ft.	In.
Sandstone, massive.....	10	0
Clay, light, plastic.....	3	6
Coal, bony.....		$\frac{1}{4}$
Clay, dark, plastic.....		9
Coal, bony.....		1
Clay, dark, plastic.....		10
Coal, bony.....		2
Clay, light, plastic, siliceous.....	1	10
Coal, <i>Lower Kittanning</i> , not full thickness.....	2	0

Oak Hill

The above record shows the composite nature of the bed so frequently observed at other places in southern Ohio, and its association with coal, probably correlative with the Strasburg member. Its position here is also directly above the Lower Kittanning coal as it is in the main field near Oak Hill in Jackson County. Deposits from 3 to 6 feet thick are present locally along the ridges in the northwestern part of the township. Along Sandy Run the member is moderately steady. Its position is commonly from 5 to 15 feet above the Lower Kittanning coal. The stratigraphic relations of the Oak Hill clay to other beds is well shown in the following record taken along the road in the central part of Section 7:

	Ft.	In.
Sandstone, massive, soft.....	80	0
Coal blossom, <i>Middle Kittanning</i>	2	0
Shale and covered.....	27	0
Clay, light, plastic, siliceous, <i>Oak Hill</i>	4	0

	Ft.	In.
Shale and shaly sandstone, gray.....	15	6
Coal, weathered, <i>Lower Kittanning</i>	1	4
Clay, light, plastic.....	3	0
Sandstone, argillaceous, light.....	2	0
Sandstone, massive, soft.....	32	0
Shale, black, fissile.....	6	0
Coal, <i>Clarion</i>	1	1

This clay was observed also at several places in the vicinity of Hope Station and along Raccoon Creek to the west. The quality of the Oak Hill clay in Brown Township is so far surpassed by that of the Clarion and Lower Kittanning members that its use is not advised. At most it is fitted only for the manufacture of building brick and hollow block.

Swan Township.—Owing to the rise of the rocks to the west, only a few of the ridges and knobs in the eastern part of Swan Township are sufficiently high to contain deposits of Oak Hill clay. The bed lies nearly 1,000 feet above tide in Section 12, 960 feet in Section 27, and 920 feet in Section 36. It is a siliceous, plastic clay of medium quality. Neither the thickness nor the stratigraphy is unusual.

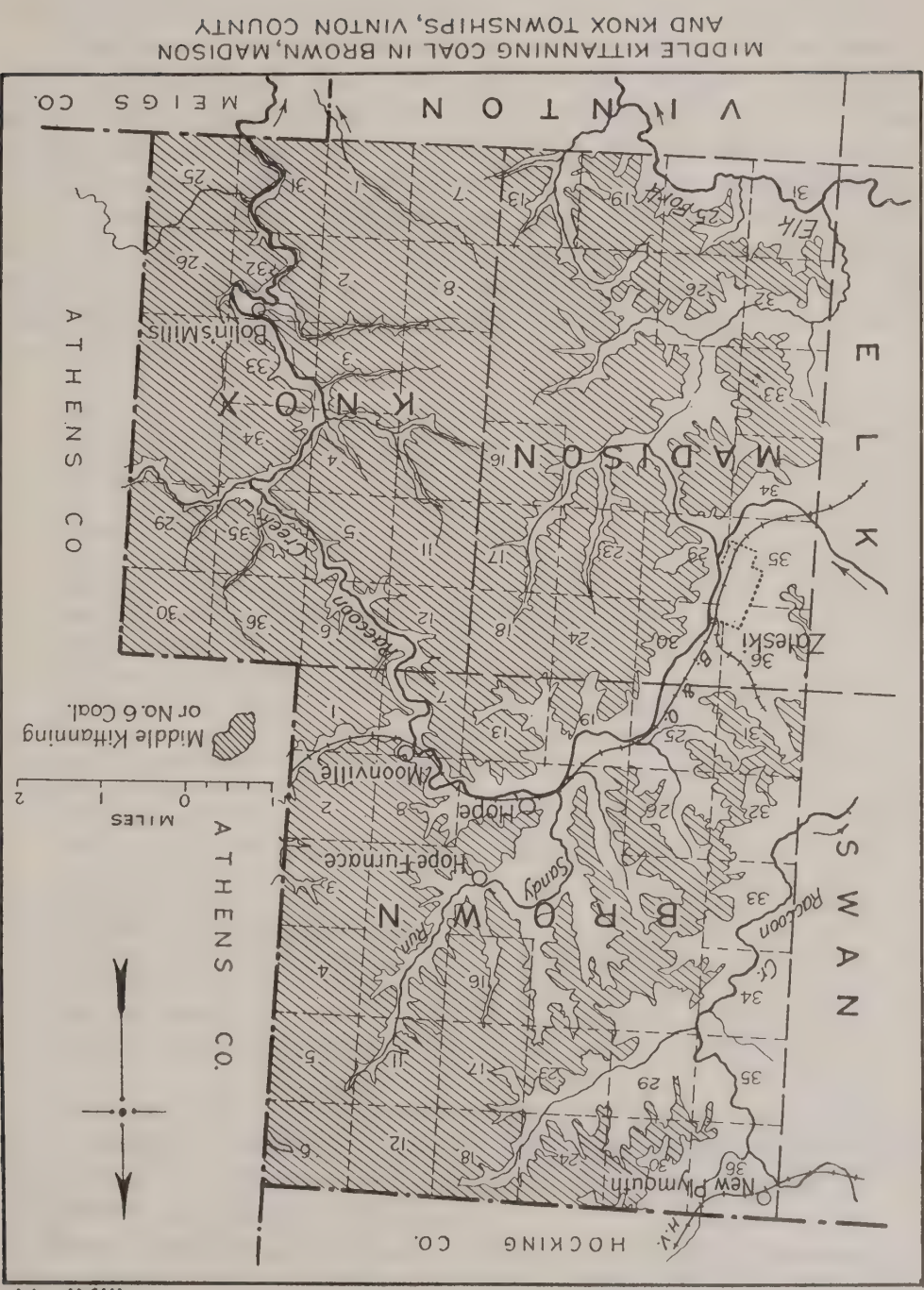
Elk Township.—In Elk Township the deposits of Oak Hill clay are confined entirely to the ridges in the eastern part. They are not attractive for ceramic use. The thickness of the Oak Hill clay at this place is from 3 to 6 feet. The following record taken in the southeastern part of Section 15 shows its position with respect to the Kittanning coals:

	Ft.	In.
Coal blossom, <i>Middle Kittanning</i>	1	0
Shale and covered	22	6
Coal smut, <i>Strasburg</i>		$\frac{1}{4}$
Clay, plastic, dark, <i>Oak Hill</i>	4	6
Coal, <i>Lower Kittanning</i>	1	4
Clay, light, plastic.....	3	8

In both the northeastern and southeastern parts of the township, the Oak Hill member is locally replaced by sandstone. Where present its position is only a few feet at most above the Lower Kittanning coal. No flint clay was observed on the horizon at any place within the township. The overlying Strasburg coal is at few places represented by more than a soot streak of carbonaceous matter.

Madison Township.—The position of the Oak Hill member is near the ridge summits in the western part of Madison Township and not far above the valley floors in the eastern part. Along Raccoon and Wheelabout creeks in the northern part of the area the bed is moderately persistent but along Elk Fork and Flat Run in the

MAP IV



southern part, both it and the Lower Kittanning coal are usually absent, their place being taken by sandstone. The deposits vary in thickness from 3 to 8 feet. In general the quality of the material is poor.

In the central part of Section 30 the member, lying 875 feet above tide, is a dark, plastic clay with concretionary matter in the basal portion. It is separated from the Lower Kittanning coal by 16 feet of shale and sandstone and from the Middle Kittanning coal by 17 feet of similar material. In sections 17, 23, and 29, the member is usually present with fair development. Few deposits were observed along the ridges in the vicinity of "the Pinnacle" in sections 33 and 34. The following record, taken in the northwestern part of Section 16, is representative of the Oak Hill member on the headwaters of Wheelabout Creek:

	Ft.	In.
Shale, gray.....	8	0
Clay shale, red, horizon of <i>Upper Freeport</i> coal.....	3	0
Shale and covered.....	2	0
Clay, light, <i>Bolivar</i>	2	0
Sandstone, shaly.....	3	0
Shale and covered.....	22	0
Clay shale and covered.....	3	0
Limestone, nodular, fresh water, in clay, <i>Lower Freeport</i>	1	0
Clay, calcareous, light to dark.....	4	0
Sandstone, massive, soft.....	43	0
Shale, dark, part bony.....	1	0
Shale, gray.....	8	0
Coal blossom, <i>Middle Kittanning</i>	1	0
Shale and covered.....	14	0
Clay, plastic, dark... }	1	0
Clay, with impure limestone nodules.. }	1	0
Clay, plastic, light... }	3	0
<i>Oak Hill</i> , altitude 800 feet		
Shale, shaly sandstone, and covered.....	17	0
Coal blossom, <i>Lower Kittanning</i>	1	0
Clay and covered.....	5	0
Shale and covered.....	14	0
Sandstone, massive, <i>Kittanning</i>	30	0

The Oak Hill member improves more in quality and becomes more unsteady on Elk Fork in sections 19, 25, and 31 and on Flat Run in Section 13. Aside from the stratigraphic features this clay is of little interest in Madison Township.

Knox Township.—In Knox Township the Oak Hill member is present not far above the floor of Raccoon Creek from the Brown-Knox Township line in Section 12 southward to near Bolins Mills in Section 32. It appears also at a few places on Tedroe, Merritt, and Russell runs. Owing to its position near the level of the flood plains or at the base of the hills, the bed is not in many places exposed for examination. Where observed it is a siliceous, plastic clay of low purity.

The usual thickness is between 4 and 6 feet. The following record was taken on Russell Run in the northeastern part of Section 8:

	Ft.	In.
Sandstone, massive.....	30	0
Shale, with bone layers.....	2	4
Coal, <i>Middle Kittanning</i> , weathered.....	1	4
Shale, gray, siliceous.....	14	0
Clay, dark, plastic, impure.....	2	0
Clay with nodules of ferruginous and calcareous matter.....	Oak Hill, altitude 740 feet	6
Clay, light to dark, plastic, impure....		2
Clay with large masses of ferruginous limestone, <i>Hamden member</i>		0
Stream bed.		

In Knox Township the position of the Oak Hill clay is about midway in the interval between the Lower Kittanning and the Middle Kittanning coals. No flint clay was observed on the horizon at any place within the area. The purity of the plastic clay is not such as to warrant its use for ceramic products.

Vinton Township.—In Vinton Township the Oak Hill member has few features of interest either stratigraphic or economic. Although due above drainage along all the larger streams, the bed is present at few places as it is replaced in large areas by sandstone. In general the deposits observed are thin, measuring less than 5 feet. The clay is plastic and siliceous and high in basic fluxes. The stratum is best developed along Pierce Run in the west central part of the township and along Zinns Run in the southeastern part.

Clinton Township.—The Oak Hill clay in parts of Clinton Township takes on some of the lithologic and geologic features it has in the Oak Hill district of Jackson County. The deposits yield both flint and plastic clay, are situated on or only a few feet above the Lower Kittanning coal, contain little concretionary matter, and have a rather uniform deposition. The bed is confined to the ridges in the eastern half of the township. Throughout this field the stratum is moderately persistent except in the northeastern part, where it gives way locally to sandstone.

In the eastern part of Section 15 the Oak Hill is a plastic clay more than 6 feet thick. Its elevation is 910 feet above tide and 30 feet above the Lower Kittanning coal, the intervening material being a soft, micaceous sandstone. The member is thus represented also in the central part of Section 16 and in the northern parts of sections 21 and 22 except that it lies much closer to the Lower Kittanning coal. Locally flint clay along with the plastic marks the horizon in sections 23, 24, 25, 26, and 27. The stratigraphic features are well shown in

the following record, taken at the mines of the McArthur Brick Company in the northeastern part of Section 28:

	Ft.	In.
Shale.....	3	0
Coal, rough.....	1	6
Clay, impure.....		3
Coal, good.....	1	2
Clay shale.....		1
Coal, good.....		10
Clay and covered.....	10	10
Shale, gray.....	6	0
Sandstone, shaly.....	7	0
Shale, gray.....		2
Clay, plastic, dark.....		8
Clay, plastic, light.....	1	0
Coal, very bony.....		10
Shale, dark, carbonaceous.....		8
Clay, plastic, dark.....		5
Clay, flint, gray.....		9
Clay, plastic, gray.....		4
Coal, fair quality, <i>Lower Kittanning</i>	1	4
Clay, plastic, light.....	5	0
Shale and shaly sandstone.....	22	0
Covered.....	4	0
Limestone, <i>Vanport</i> , 4 to 10 feet.....	8	0
Shale, black, bony.....	1	6
Coal, rough.....		2
Clay, impure.....		6
Coal, good.....	1	4
Clay with pyrite.....		1½
Coal, good.....		11
Clay, plastic, good.....	9	0

At this place the Oak Hill clay has the composite structure that is evident in small areas elsewhere in Vinton County and south of this in Jackson, that is, it is made up of two or more strata of clay which differ in character and quality and which are separated by partings of coal, coaly smut, or carbon-stained clay. The flint clay found here is similar in texture, color, and composition to that on the Oak Hill horizon near Oak Hill in Jackson County. In a general way the thin coal lenses associated with the Oak Hill clay in southern Ohio are correlative with the Strasburg coal in the Strasburg field of eastern Ohio.

Wilkesville Township.—The Oak Hill clay is due above drainage along all the larger streams in the western half of Wilkesville Township. The member, however, adds little to the ceramic resources of the region as the bed is wanting in large areas and as where present it consists almost entirely of low grade, plastic clay. Where observed the thickness of the stratum is less than 5 feet. Its position is about midway in the interval between the Lower Kittanning and the Middle Kittanning coals.

Economic value

In the entire field in Vinton County the Oak Hill member is wanting in some qualities essential for satisfactory ceramic work. On this account it has not been employed directly as the basis for clay products at any place within the county. It has been used only at the Puritan plant of the McArthur Brick Company near Hamden where it was mined incidentally with shale for making vitrified shale brick. The Oak Hill clay ranks far below the Clarion, Lower Kittanning, and Brookville beds upon which alone such operations should be based.

The Oak Hill clay in this field is entirely plastic in character except small lenses of flint clay, confined largely to southeastern Clinton Township. The most damaging impurities are concretions of ferruginous and calcareous matter which vary in size from microscopic dimensions to 1 foot or more. The larger masses are usually somewhat concentrated into definite layers bedded in the lower or the middle portion of the deposits. The fine, seed-like concretions are commonly disseminated through the entire stratum. Locally this clay contains also apparent quantities of pyrite crystals, mica flakes, and quartz sand. The chief coloring pigments are carbonaceous matter and iron compounds. The Oak Hill clay in Vinton County may be safely recommended only for the more common kinds of ceramic products.

MIDDLE KITTANNING COAL

Stratigraphy and extent

The Middle Kittanning is not only the most important but is the most persistent coal bed in the Pennsylvanian system of Ohio. With few wants and not many large areas of impoverishment this coal outcrops in a narrow belt extending from the Ohio-Pennsylvania State line in Columbiana County southwestward to the Ohio River in Lawrence County. The bed is mined in either a large or a small way in Columbiana, Jefferson, Mahoning, Stark, Carroll, Tuscarawas, Holmes, Harrison, Guernsey, Coshocton, Muskingum, Perry, Morgan, Hocking, Athens, Vinton, Gallia, Jackson, and Lawrence counties. In thickness the stratum varies from a few inches to 16 feet but the mean measurement is about 3 feet 6 inches. The Middle Kittanning coal lies, on the average, nearly 33 feet above the Lower Kittanning coal, 61 feet above the Vanport limestone, 47 feet below the Lower Freeport coal, and 95 feet below the Upper Freeport coal. It correlates with the Coalton or No. 7 coal in Kentucky to the south and with the Middle Kittanning or No. 6 coal in Pennsylvania to the east. In Ohio the bed is known locally as the Sheridan, Hocking Valley, Coshocton, Pike Run, and Washingtonville.

In Vinton County the Middle Kittanning or No. 6 coal is present above drainage in the eastern part in Brown, eastern Elk, Madison, Knox, Vinton, eastern Clinton, and western Wilkesville townships. The main reserve of minable coal is in Brown Township. In the remainder of the area the bed is thin, less than 2 feet 6 inches in thickness, except in small areas where it expands to 3 feet or more. From nearly 100 measurements taken throughout the field, the mean thickness of coal and partings is 2 feet 6 inches of which 2 feet 2 inches is coal and 4 inches clay shale. The maximum thickness observed is 4 feet 6 inches and the minimum 4 inches. In a general way the bed decreases rather uniformly southward from Brown Township to Wilkesville Township.

Normally the Middle Kittanning member is divided into three coal benches by two clay shale partings. The lower bench of coal varies in thickness from 1 inch to 1 foot 3 inches but averages nearly 4 inches. It is best represented in Brown Township where the usual variation is between 4 and 8 inches. The lower parting, an impure clay shale, is very persistent and uniform and has a mean thickness of 1 inch, with little contraction or expansion. The middle bench of coal is by far the best developed, and in places it alone represents the member. It decreases southward from a maximum thickness of 2 feet 9 inches in the main basin in Brown Township to the much impoverished part of the field in Wilkesville Township where the minimum measurement is 4 inches. From the data gathered the average thickness is 1 foot 8 inches. The upper parting, like the lower one, is characterized by remarkable uniformity in that it changes little from the 3 inch thickness and only slightly in kind of material. The upper bench of coal, everywhere impure, is absent in many areas from various causes. It is erratic in thickness, expanding from 1 inch to 1 foot 6 inches but averaging only about 2 inches. The great thickness of the Middle Kittanning coal in the Hocking Valley field in Athens, Hocking, and Perry counties is due more to enlargement of the upper bench than to that of the middle and lower ones. In the Sheridan field of Lawrence County the middle bench of coal alone is present.

In Vinton County the Middle Kittanning coal lies commonly 38 feet above the Lower Kittanning coal, 73 feet above the Vanport limestone, 84 feet above the Clarion coal, 56 feet below the Lower Freeport coal, and 98 feet below the Upper Freeport coal. These intervals are fairly constant except where massive sandstones appear in the section. In the northern part of the field the bed is usually directly overlain by sandstone whereas in the southern part it is covered by a few feet of shale upon which the sandstone rests. The floor of the coal is everywhere an impure clay tending strongly towards shale, and the regular partings are of similar material.

The dip of the Middle Kittanning coal to the south from Section 18, Brown Township, to Section 9, Wilkesville Township, is 9.1 feet per mile; and from Section 13, Swan Township, to Section 29, Huntington Township, Gallia County, it is 13.3 feet. The descent of the bed to the east is much greater than this. Between Section 23, Swan Township, and Section 33, Waterloo Township, Athens County, it dips 30.5 feet per mile, and between Section 22, Milton Township, Jackson County, and Section 9, Wilkesville Township, 30.6 feet.

Brown Township.—The field of Middle Kittanning coal in Brown Township is much the most important reserve of fuel in Vinton County. The area of coal is 19.24 square miles. The bed is persistent, is rather uniform in thickness, is above drainage except in the northeastern part of the area, is so dissected that it is open to attack, has been little depleted by mining, and is all within reach of the present railroads. In some respects mining conditions are good. The roof is commonly a sandstone, massive and strong, and the floor is a siliceous clay, well able to carry the weight of the overburden. Under such conditions a yield of 70 per cent or more of the coal should be obtained. Further, the stratum has a rather uniform dip to the east and south which may be advantageously employed in draining the mine and in hauling the fuel. The chief objections are the small thickness of the member for mining in a large way, the presence of two clay shale partings, and the bony character of the coal in the upper bench. From thirty-five measurements in Brown Township the mean thickness of the bed is 3 feet 8 inches and that of clean coal in the middle and lower benches is 2 feet 9 inches. The upper bench of coal averages about 7 inches. Although bony in character, the bed contains some good fuel and may be economically employed for local use. The service promising most returns for the Middle Kittanning coal in this area is not for direct marketing but for converting into first-class clay products the Clarion clay, which has a wide range of usefulness and lies about 80 feet below.

In Section 6 the Middle Kittanning coal appears at the surface, 820 feet above tide, only along the stream in the northeastern part. Where exposed on the property of Sherman McDaniel it has the thickness and structure shown below:

	Ft.	In.
Sandstone, massive.....	5	0
Shale, gray, fair roof.....	3	0
Coal, bony.....	} Middle Kittanning, altitude 820 feet	11
Clay, impure.....		4
Coal, good.....		3
Clay, impure.....		1
Coal, good.....		6
Stream bed.		

This coal is everywhere below drainage in Section 12 but appears along the streams in the western part of Section 18, where it shows improvement in thickness. Its position is approximately 41 feet above the Lower Kittanning coal and 120 feet below the Upper Freeport member. The Middle Kittanning coal has been mined for local use at several places. The following measurements were taken at the bank of William Carter in the central part of the area:

	Ft.	In.
Sandstone, massive.....	20	0
Shale, gray, fair roof.....	2	0
Coal, fair.....	2	11
Clay, shaly.....		3
Coal, good.....		8
Clay shale.....		1
Coal, good.....		11
Coal, bony.....		2
Clay, siliceous.....	1	0

Middle Kittanning, altitude 850 feet

At this place the coal in the upper bench is of fair quality as it has only a few thin, bony layers. For many purposes, it may be used with the coal below, thus increasing the yield of the bed with only slight loss in efficiency. The fuel in the lower and middle benches is very good. The overlying shale has sufficient strength to allow mining in a large way. The member thins gradually in its extension westward through Section 24 into Section 30. Such deposits in Section 36 are confined to a few high knobs in the southeastern part, where the stratum lies 960 feet above tide. Conditions are similar in sections 35 and 29. Owing to the dip of the bed to the east and to the rise of the hills, a large body of good fuel is present in the southern part of Section 23, where the following record was taken in a prospect mine on the property of G. P. Drayer:

	Ft.	In.
Sandstone, massive.....	25	0
Coal, bony.....	2	3
Clay, impure.....		4
Coal, good.....		6
Clay shale.....		1½
Coal, good.....		6
Covered.....	35	0
Coal, <i>Lower Kittanning</i> , reported thickness.....	5	0

Where measured in a local mine on the property of Eli Weed in the northeastern corner of Section 23, the structure is as follows: lower bench of coal 1 foot, one-half inch, lower parting 1 inch, middle bench of coal 2 feet 8 inches, upper parting 3 inches, and upper bench of coal 4 inches. The member is overlain by 75 feet of massive sandstone. Its position is 26 feet above the Lower Kittanning coal and 86 feet above

the Clarion coal. In Section 17 no openings were found but outcrop exposures indicate normal thickness. In a mine on the property of J. V. Hull on Sandy Run in the central part of Section 11, a sample was taken for analysis. (See page 332.) The section of the bed in detail follows:

	Ft.	In.
Sandstone, massive.....	36	0
Coal, upper bench, sampled.....	2	7½
Clay and bone, rejected.....		2¼
Coal, hard, sampled.....		4
Clay, rejected.....		1½
Coal, sampled.....		6

Middle Kittanning,
altitude 804 feet

The coal in the upper bench is of fair quality and hence was sampled for testing as it may be used for most purposes. At this place the position of the bed is 68 feet below the Lower Freeport limestone, 103 feet below the Bolivar flint clay, and 157 feet below the Mason coal in the Conemaugh formation. Other openings in this vicinity show that the Middle Kittanning coal retains the thickness shown above over a rather wide area. Near the head of Sandy Run in the north-western part of Section 5, the member passes below cover at an elevation of 800 feet. The structure of the member on the property of the Hocking Coal Company is as given below:

	Ft.	In.
Sandstone, massive.....	15	0
Coal, fair quality.....	2	6
Coal, bony.....		2
Clay, impure.....		3
Coal, good.....		3
Clay shale.....		1½
Coal, good.....	1	6
Clay, impure.....		0

Middle Kittanning

The Middle Kittanning coal is everywhere below drainage in Section 4. West of this on Sandy Run it lies about 80 feet above the valley floor, but no openings were found to show its thickness and structure. In Section 16 this coal outcrops only in the deep valleys and was not favorably exposed for measurement. At the head of the hollow north of Hope Furnace, near the residence of Charles Hayborn, the member has good thickness and quality. Measurements secured in a local mine are given below:

	Ft.	In.
Sandstone, massive.....	6	0
Coal, somewhat bony..	2	8
Clay, impure.....		3
Coal, good.....		8
Clay, shaly.....		1
Coal, good.....		9
Clay, impure.....	2	0

Middle Kittanning, altitude 890 ft.

On the property of G. P. Drayer south of this place, the Middle Kittanning coal was also exposed in a prospect opening. The thickness is practically the same as shown above, that is, the coal benches measure 9 inches, 2 feet 7 inches, and 9 inches respectively, and the clay partings 1 inch and 3 inches. The roof is sandstone more than 50 feet thick. The position of the Middle Kittanning coal here is nearly 80 feet above the Clarion coal. On the main ridge in the south central part of what would be Section 28 if consistently numbered, the Middle Kittanning coal has been mined in a small way on land of G. P. Drayer. The record obtained is given below:

	Ft.	In.
Sandstone, massive.....	15	0
Coal, bony.....	} <i>Middle Kittanning</i> , altitude 860 ft. 2	8
Clay, shaly.....		3
Coal, good.....		6
Clay, impure.....		1
Coal, good.....		6

The member is also worked for household fuel on the knob just south of the mouth of Twomile Run on the same property. The section differs little from that shown above. The mouth of the mine lies 905 feet above tide. The member lies so close to the ridge tops in Section 34 that the deposits of coal are small and unimportant. Conditions are similar in Section 33. Near the head of the west fork of Wildcat Hollow on land of G. P. Drayer, coal has been mined from the Middle Kittanning member here exposed under a sandstone cliff. A sample was taken for testing. (For analysis, see page 331.)

	Ft.	In.
Sandstone, massive.....	30	0
Shale, gray.....		8½
Coal, somewhat rough, sampled.....		7½
Clay and bone coal, rejected.....		4½
Coal, good, sampled.....	1	½
Mother coal with pyrite, sampled.....		1
Coal, good, sampled.....	} <i>Middle Kittanning</i> 1	5
Clay shale, rejected.....		1
Coal, good, sampled.....		5
Clay, siliceous.....	1	0

At this place the upper bench of coal has the quality to warrant its use for common purposes; hence it was sampled for testing. The mother coal varies from a thin, papery parting to 2 inches in thickness. In it the pyrite is concentrated into flakes and irregularly shaped concretions. The fuel in the remainder of the bed is very good. The shale lying between the coal and the sandstone is variable in thickness; and on exposure to the air it loosens, thus requiring its removal in mining. The true roof of the coal is massive sandstone which is so

solid and durable that little posting is necessary in properly operated mines. In its extension southward along this stream the Middle Kittanning coal thins slightly and the upper bench becomes more bony in character. This condition is shown in the following record, taken at the "Horse Cave" near the mouth of Wildcat Hollow, where a sample for testing was cut through the face of the coal. (For test, see page 331.)

	Ft.	In.
Sandstone, massive	30	0
Coal, bony, rejected		8
Clay and bone shale, rejected		4½
Coal, good, sampled	2	3¼
Clay, impure, rejected } <i>Middle Kittanning</i> , altitude 840 feet		2
Coal, good, sampled		4¾
Clay, siliceous		1	0

In the vicinity of Hope Furnace the Middle Kittanning coal has been mined in a small way for local use. Where opened just west of the furnace stack, the measurements are, lower bench of coal, 5 inches; lower parting, 1 inch; middle bench of coal, 2 feet 4 inches; upper parting, 3 inches; and upper bench of bony coal, 6 inches. The member is separated from the overlying sandstone by 5 inches of shale, and its position is 37 feet above the Lower Kittanning coal and 101 feet above the Clarion coal. In King Hollow in the southeastern part of Section 3, the bed is mined by drifting for household use. A record taken there is given below:

	Ft.	In.
Sandstone, soft, massive.....	10	0
Shale, gray, fair roof.....	4	4
Coal, bony.....	} <i>Middle Kittanning</i> , altitude 750 feet	7
Clay, impure.....		4
Coal, good.....		3
Clay shale.....		1½
Coal, good.....		8½
Clay, siliceous, shaly.....		1	0

Formerly near Ingham in the southeastern part of Section 2, the Middle Kittanning coal was mined in a large way for railroad shipment. The thickness and structure reported are much the same as those shown above. At this place the member lies near the base of the hills at an elevation of 750 feet. In its extension westward into Section 8 the member thins somewhat, due to a slight contraction of each coal bench. The following record, taken on land of the Ohio Oil Company in the northwestern part of the area, is representative:

	Ft.	In.
Sandstone, massive.....	30	0
Coal, bony.....	} <i>Middle Kittanning</i> , altitude 820 feet	6
Coal, shaly.....		4

		Ft.	In.
Coal, good.....	} <i>Middle Kittanning</i> , altitude 820 feet	2	1
Clay, impure.....			1
Coal, good.....			5
Clay, very siliceous, shaly.....		2	0

In this locality the upper bench of coal is so bony that it is of little value as fuel. It is also charged with pyrite which impairs its strength as roof material. On exposure to the air the pyrite is converted into ferrous sulphate with such an increase in volume that the coal stratum is shattered and falls. At Hope Station the Middle Kittanning coal was formerly mined for shipment by the Oliver Coal Company. It is worked at several places near by for household fuel. The following section is about representative for that north of the Baltimore and Ohio Southwestern Railroad:

		Ft.	In.
Sandstone, massive.....		40	0
Coal, bony.....	} <i>Middle Kittanning</i> , altitude 840 feet		6
Clay, shaly.....			3
Coal, good.....		2	3
Clay, impure.....			1
Coal, good.....			5
Clay, siliceous, shaly.....		2	0

South of the railroad the upper bench of coal is wanting or is represented only by thin lenses of coal in clay. The middle bench averages about 2 feet 1 inch in thickness and the lower bench nearly 5 inches. The roof everywhere is massive sandstone. Along Little Sandy Run the member varies slightly in thickness, structure, and quality from that at Hope Station. No improvement was evident either in Section 26 or in most of Section 32. A small area of thick coal, however, is present in Section 31. Where mined for shipment by the Blanchard Coal Company in the northwestern part of the area, the bed has the measurements given below:

		Ft.	In.
Sandstone, parts covered.....		52	0
Shale and covered.....		5	0
Coal, fair quality.....	} <i>Middle Kittanning</i> , altitude 903 feet		9
Coal, bony.....			2
Clay, impure.....			4
Coal, good.....		2	9
Clay shale.....			1
Coal, good.....			8
Clay, siliceous, shaly.....		2	0

In this mine the upper bench of coal thickens to 1 foot 3 inches and the lower bench to 1 foot. The position of the member is 22 feet above the Lower Kittanning coal, 67 feet above the Clarion coal, 105

feet above the Brookville coal, and 122 feet above the Upper Mercer limestone. Formerly large quantities of fuel were mined from this bed in "Bung Hole" Hollow in the northeastern part of Section 31, where the total thickness of the member is reported to be nearly 4 feet 6 inches and that of good coal 4 feet 2 inches. Much of this fuel was shipped to Cincinnati for making artificial gas, and to Zaleski and other points on the Baltimore and Ohio Southwestern Railroad for steam generation. In the mines here both Andrews and Orton observed the presence of quartzite boulders bedded in the coal and also in the overlying shale.¹ Such occurrences, however, appear to be local. The deposits of Middle Kittanning coal in Section 25 are small as the bed has been largely removed by erosion. In Section 19 the bed is generally thin. A representative record taken on the property of G. P. Drayer in the south central part of the area follows:

	Ft.	In.
Sandstone, massive.....	53	0
Clay shale.....	2	3
Coal, good.....		1
Clay, impure.....		1
Coal, good.....		5½

Middle Kittanning, altitude 845 feet

At this place the upper bench of coal is wanting as it was removed by erosion before the overlying sandstone was deposited; hence the member is made up of two coal benches instead of three, the normal number. The Middle Kittanning coal lies nearly 100 feet above the Clarion coal and 200 feet below the Brush Creek member, here represented by black flint. In Section 13 conditions are much the same. The thickness of the lower bench of coal is from 5 to 7 inches and that of the middle bench from 1 foot 10 inches to 2 feet 5 inches. In small areas sandstone replaces part of the middle coal stratum. The bed is mined in a small way on the farms of Albert Pinney, Ira Pinney, and John Burt. At Moonville in Section 2 the Middle Kittanning coal has been worked for shipment. In a mine on the property of A. E. Kennard a sample was taken for analysis. (See page 332.) The structure of the member is given below:

	Ft.	In.
Sandstone, massive, roof.....	20	0
Coal, rough, sampled.....	1	4¼
Clay and bony coal, rejected.....		4½
Coal, good, sampled.....		11½
Clay, shaly, rejected.....		1½
Coal, good, sampled.....		4¾
Clay, siliceous, floor.....	2	0

In this locality the bed lies approximately 785 feet above tide and 100 feet above the flood plain of Raccoon Creek. In Section 1 the member improves little either in thickness or in quality.

¹Geol. Surv. Ohio, Rep. of Progress 1870, p. 78, and Vol. V, p. 1,005.

Swan Township.—In Swan Township the deposits of Middle Kittanning coal are small as they are confined to a few high knobs and ridges in the eastern part. The elevation of the bed is 990 feet in the southeastern part of Section 13, 1,000 feet in the central part of Section 23, and 950 feet in the central part of Section 36. The coal has been mined only in a small way in the eastern part of Section 36 where the following record was taken in a drift mine on the property of Mary J. Webb:

	Ft.	In.
Sandstone, massive.....	60	0
Coal, bony.....	2	8½
Clay, shaly.....		3½
Coal, good.....		10
Clay, shaly.....		1
Coal, good.....		5
Clay, siliceous, shaly.....	2	0

Much of the coal in this ridge has been removed through the extension of the mines formerly operated in Strong Hollow in Section 31, Brown Township. The quality of the fuel is very good.

Elk Township.—The Middle Kittanning coal is an asset of little importance in Elk Township as the deposits in the northeastern part are generally small and those in the southeastern part are thin and bony. It contributes some fuel, however, for local consumption. At present (1925) it is worked in only one locality, near McArthur.

In Section 1 the member is present near the summits of the high ridges at an elevation of 940 to 950 feet. The coal is reported to be about 3 feet thick. Small bodies of coal occur 960 feet above tide on the two high knobs in the southeastern part of Section 2. On the Stephen Cramm farm in the central part of Section 11, the member has been prospected by drifting and is reported to be more than 3 feet thick. The roof is a massive sandstone. At this place the Middle Kittanning coal lies 74 feet above the Clarion coal. The blossom of the member was also observed near the summits of a few knobs in the western part of Section 14 and the eastern part of Section 15. The area of most importance is in the northeastern part of Section 22 where the bed has been worked in a small way for many years for household fuel at McArthur. At the mine of Jacob Morgan the following measurements were obtained:

	Ft.	In.
Shale, gray, siliceous.....	5	0
Coal, bony.....	2	6
Clay shale.....		3
Coal, good.....		8
Clay shale.....		1
Coal, good.....		4
Clay and covered.....	3	0

The lower and middle benches of coal are very free from impurities but the upper bench is shaly. The deposits lie in a small, synclinal basin much below the normal in elevation. In Section 24 a thin blossom of Middle Kittanning coal is present 920 feet above tide on a few high knobs in the eastern part of the area. The bed is largely replaced by sandstone in sections 35 and 36.

Madison Township.—The Middle Kittanning coal is above drainage along all the larger streams in Madison Township. It is generally thin and in some localities it is replaced by sandstone. In a general way the thickness of the member decreases gradually in its extension southward across the area. The deposits worked most for household fuel are those along Raccoon and Wheelabout creeks in the northern part of the township where the average thickness of the middle and lower benches of coal is nearly 1 foot 9 inches and 7 inches respectively. The upper bench of coal is either absent or very shaly in character. The geological features are not unusual.

In Section 36 the Middle Kittanning coal was formerly mined for shipment. The member is reported to be 4 feet 6 inches thick of which 4 inches is parting and 8 inches bony coal. The deposits are much thinner in sections 30, 24, and 18. The following record, taken in a small mine on the property of Robert F. Dixon located in the north central part of Section 17, is representative of the bed in this locality:

	Ft.	In.
Sandstone, massive.....	15	0
Shale, gray, siliceous.....	1	3
Coal, shaly.....	2	4
Clay, impure.....		2
Coal, good.....		0
Clay shale.....		1
Coal, good.....		5
Clay, siliceous.....	1	0

Middle Kittanning, altitude 810 feet

The bed has been mined both by drifting and by stripping at a few places south of this on the headwaters of Wheelabout Creek. Where observed the middle bench of coal measures from 1 foot 4 inches to 1 foot 10 inches and the lower stratum from 4 to 6 inches. The upper bench of coal is generally absent through lack of deposition. In the northeastern part of Section 23 the Middle Kittanning member appears with fair development in a small area. Measurements taken in a drift mine on the property of Wilson Chesser are given below:

	Ft.	In.
Sandstone, massive.....	2	0
Shale, carbonaceous.....	1	0
Shale, gray.....	4	.2

		Ft.	In.
Coal, fair.....	} <i>Middle Kittanning</i> , altitude 805 feet	1	2
Shale, coaly.....			3
Coal, good.....			9½
Clay, impure.....			1
Coal, good.....		1	2½

No openings were found in Section 29 where the member is reported to be about 3 feet thick. South of Raccoon Creek in the vicinity of "the Pinnacle," the Middle Kittanning coal is thin and locally absent. The horizon is poorly marked also on the ridges near Prattsville and Vinton Furnace. Outcrop exposures indicate that the best developed deposits are less than 1 foot 6 inches thick. Along Raccoon Creek and Flat Run in the southeastern part of the township the member is more often absent than present and the interval is largely taken by massive sandstone.

Knox Township.—The Middle Kittanning member in Knox Township is of interest because it provides small supplies of domestic fuel in a region where other coal beds are poorly developed. It is very persistent, at few places being wanting through replacement or through lack of deposition. From many measurements the mean thickness of clean coal in the deposits is 2 feet 2 inches. It is widely distributed throughout the area. The member appears above drainage along Raccoon Creek throughout its entire length in the township and along the lower courses of its larger tributaries, Onion Creek, Tedroe Run, Merritt Run, and Russell Run. In a general way the member thins slightly in its extension southward.

In the deep hollow west of Raccoon Creek in the central part of Section 12, the Middle Kittanning coal was exposed in a small mine on the property of Cyrus McKibben. The record follows:

		Ft.	In.
Sandstone, soft, massive.....	} <i>Middle Kittanning</i> , altitude 760 feet	1	0
Clay and bone.....			7
Coal, good.....			7
Clay, shaly.....			2
Coal, good.....			11

At this place the middle bench of coal varies from 1 foot to 1 foot 10 inches in thickness. Its position is approximately 110 feet below the Upper Freeport coal and 220 feet below the Brush Creek limestone. Where observed along Raccoon Creek in Section 6 the structure is lower bench of coal, 6 inches; lower parting, 1 inch; middle bench of coal, 1 foot 8 inches; upper parting, 2 inches; and upper bench of bony coal, 4 inches. The member is overlain by 4 to 6 feet of shale and this in turn by massive sandstone. On Laurel Run in the southeastern part of Section 36 the Middle Kittanning coal passes below drainage

at an altitude of 750 feet. The deposit has been prospected by drifting near the forks of the road on the north tributary of Onion Creek in the west central part of Section 29. The middle bench of coal is reported to be 1 foot 10 inches in thickness and the lower bench 6 inches. It lies 696 feet above tide. On Raccoon Creek in the west central part of Section 35 on the land of Elmer Webb, the member is mined for household fuel. The thickness and structure of the coal and the character of the associated rocks are shown in the record given below:

	Ft.	In.
Sandstone, massive.....	10	0
Shale, gray, siliceous.....	5	0
Shale with thin bands of bony coal.....	} <i>Middle Kittanning</i> , altitude 710 feet	3
Coal, good.....		10
Shale, carbonaceous..		$\frac{1}{2}$
Coal, good.....		8
Ganister, dark gray, hard.....		2
Clay, siliceous, impure.....	1	0

This member has also been worked in a small way at several places in the southern part of the section. The thickness of clean coal is from 2 feet 2 inches to 2 feet 8 inches. The gray shale overlying it makes a fair roof for drift mining. Conditions are much the same on Raccoon Creek in the northeastern part of Section 5, where opened on land of W. West. At a strip mine on the Robinson farm in the northwest corner of Section 5, the following strata were exposed:

	Ft.	In.
Sandstone, massive.....	40	0
Shale and shaly sandstone, gray.....	4	6
Shale, bony, part carbonaceous.....	} <i>Middle Kittanning</i> , altitude 750 feet	8
Clay shale.....		2
Coal, good.....		5
Clay shale.....		1
Coal, good.....		$6\frac{1}{2}$
Clay, siliceous.....	2	0

The Middle Kittanning coal is everywhere below drainage in Section 11 but appears on Tedroe Run south of this where it is mined by drifting or by stripping at several places. In this locality the lower and middle benches of coal coalesce, the lower parting and upper bench of coal being absent through lack of deposition. The usual thickness of the stratum is between 1 foot 8 inches and 2 feet. Some of the stratigraphic relations are shown in the following record taken near the home of S. W. Martin:

	Ft.	In.
Flint, dark, upper bed of <i>Brush Creek</i>	2	2
Shale, sandstone, and covered.....	71	0
Coal blossom, <i>Mason</i>	1	0
Shale, sandstone, and covered.....	52	0
Clay and covered, <i>Upper Freeport</i> ?	2	0
Shale and covered.....	26	0
Sandstone, massive, parts covered.....	46	0
Shale, gray, siliceous.....	5	0
Coal, good, <i>Middle Kittanning</i> , altitude 775 feet.....	1	10
Clay, plastic, siliceous.....	2	0

Near by it was opened also on land of A. C. Hutchison and Miles Townsend. Little change in the thickness and the character of the coal was observed along Tedroe Run in Section 4, but some improvement is evident near the village of Knox in the northern part of Section 34. In the drift mine of Lester Canny located just south of the mouth of Onion Creek the record, given below, was secured:

	Ft.	In.
Sandstone, massive, coarse.....	3	0
Shale, gray, siliceous.....	4	6
Shale, dark.....		7
Coal, bony, and shale, } carbonaceous.....	} <i>Middle Kittanning</i> , altitude 690 feet	
Coal, good.....	2	9
Clay, siliceous.....	2	0

The coal here represents that in both the middle and lower benches. The lower parting is absent except for thin lenses which appear from 6 to 8 inches above the bottom of the deposit. The Middle Kittanning coal lies close to drainage level along Onion Creek in the northeastern part of Section 28 where it has been mined in the usual ways for neighborhood use. On a steep bluff near where the road crosses the stream, the following section was taken:

	Ft.	In.
Shale and sandstone, gray.....	12	0
Shale, coaly.....	} <i>Middle Kittanning</i> , altitude 690 feet	4
Clay, dark.....		3
Coal, good.....		2
Clay, siliceous.....		2

Along Raccoon Creek in the western part of Section 33 and in the northeastern part of Section 3, the stratum is persistent but thin. The member is present at an altitude of 760 feet on Russell Run in the northeastern part of Section 8. Where observed the coal is 1 foot 4 inches thick. It lies 14 feet above the Oak Hill clay and 100 feet below the Upper Freeport coal. On the W. M. Beckley farm in the north central part of Section 2, the Middle Kittanning coal was exposed in a strip mine. The record obtained is given below:

	Ft.	In.
Sandstone, massive.....	20	0
Sandstone, shaly.....	6	0
Shale, lower part dark.....	6	6
Coal, good.....	1	3
Clay shale.....	} <i>Middle Kittanning</i> , altitude 720 feet	
Coal, good.....		
		1
		5

Along the east bank of Raccoon Creek just above the bridge near Bolins Mills in Section 32, the Middle Kittanning coal is present about 7 feet above water level. It consists of one coal stratum, 1 foot 4 inches thick. The bed is directly overlain by gray shale, 2 to 3 feet in thickness, above which is a coarse-grained, argillaceous sandstone measuring more than 40 feet. The deposit lies 670 feet above tide. On the east bank of Raccoon Creek on the property of H. L. Stanneart, located in the central part of Section 32, the bed was being stripped to furnish fuel for domestic use. The rocks exposed here are shown below:

	Ft.	In.
Sandstone, massive, coarse, argillaceous.....	30	0
Shale, dark, bony.....	1	7
Coal, good.....	1	5
Clay shale.....	} <i>Middle Kittanning</i> , altitude 690 feet	1
Coal, good.....		1
Clay, siliceous, impure.....		2	0

In the extension southward into Section 31 the Middle Kittanning coal passes below drainage near the southern boundary of the area. It has been mined by stripping in a few places. Where thus worked on the Setta Gibbs farm it has the following measurement:

	Ft.	In.
Sandstone, massive.....	25	0
Shale, part bony.....	3	0
Coal, bony.....	} <i>Middle Kittanning</i> , altitude 670 feet	2
Coal, good.....		3
Clay, shaly.....		1½
Coal, good.....		2

The evidence in Knox Township and adjacent areas shows that the Middle Kittanning coal in its extension southward from the main basin in Perry and Hocking counties to the Vinton County field thins through lack of deposition and not through loss by erosion. In both localities the three coal benches and the two normal partings are all definitely represented. The partings are especially persistent in extent, regular in thickness, and uniform in character. The contraction is due mainly to impoverishment in the upper coal stratum which decreases from several feet in thickness in Perry County to a few inches in Vinton County and which changes eventually to dark, carbona-

ceous shale and then to gray shale. The middle and lower coal benches also show a progressive decrease southward with finally the disappearance of the lower one. The swamp period was approximately equal in duration in the entire basin in central and southern Ohio but conditions favorable for the growth of plant life and for the preservation of the organic matter were far greater in the Hocking field than elsewhere to the south.

Vinton Township.—Although widely distributed throughout Vinton Township, the Middle Kittanning coal is everywhere thin, averaging less than 1 foot in thickness. Further, in large areas its place is taken by sandstone. As a fuel asset even to supply local needs the bed is of trifling value. Its geological relations are much the same as they are to the north in Knox, Madison, and Brown townships where the member has better development.

Along the stream in the southwestern corner of Section 6 the Middle Kittanning coal is present near the level of the flood plain at an elevation of 690 feet. It consists of one bench of coal with a thickness of 9 inches. The roof is gray shale which is overlain by a thick sandstone. In the vicinity of Vales Mills in Section 5 the bed has been mined at a few places by stripping and by drifting. The deposits vary from 8 inches to 2 feet 6 inches in thickness. The following section taken on the property of Amos Dixon is representative of the best developed bodies of coal:

	Ft.	In.
Sandstone, massive.....	15	0
Shale and shaly sandstone.....	11	0
Coal, good.....	1	2
Clay, shaly.....	} <i>Middle Kittanning</i> , altitude 645 feet	1
Coal, good.....		9
Clay, siliceous.....	1	0

The member is poorly represented along Raccoon Creek in sections 4 and 10; along Elk Fork and its tributaries in sections 24, 23, 17, 11, and 16; along Alman Run in sections 29, 28, and 22; and along Pierce Run in sections 35, 34, 33, 27, and 21. At most the horizon is marked only by a few inches of coal, by a thin stratum of carbonaceous shale, or by small deposits of siliceous clay. Little improvement is evident in the vicinity of Radcliff. In Section 31 the member thickens locally to 1 foot 6 inches. Along the stream south of the Whiteoak School in the northeastern part of Section 7 on land of C. E. Cotterill, the following record was secured:

	Ft.	In.
Sandstone, shaly.....	4	0
Shale, siliceous.....	3	6
Coal, good.....	} <i>Middle Kittanning</i> , altitude 680 feet	5½
Clay shale.....		¼

	Ft.	In.
Coal, shaly, <i>Middle Kittanning</i> , altitude 680 feet		$\frac{3}{4}$
Clay, siliceous, impure.....	2	2
Shale, gray.....	4	0
Stream bed.		

On the south tributary of Brush Fork in the east central part of Section 3, the *Middle Kittanning* coal has been mined in a small way on the George Cummins farm. It is reported to be about 1 foot 6 inches in thickness and of fair quality. The deposit lies 680 feet above tide and near the level of the flood plain.

Clinton Township.—In Clinton Township the *Middle Kittanning* member is erratic in development as it varies irregularly from a thin stratum of bony shale to a thick bed of good coal. The deposits with sufficient thickness for drift mining are of small size, being confined largely to sections 16 and 28. The supply of fuel remaining is not large.

Along the ridge near the Tar Farm School in Section 14 a thick blossom of *Middle Kittanning* coal is present at an elevation of 920 to 935 feet. It is worked by drifting by Harry Carr in the north-eastern part of Section 16. The bed has a thickness of 3 feet 2 inches and lies 920 feet above tide. The roof is shale. At the mine of Jackson Thompson in the north central part of the same area the following record was secured:

	Ft.	In.
Sandstone, shaly.....	2	0
Shale, gray.....	3	9
Coal with shaly part-ings.....	<i>Middle Kittanning</i> , altitude 920 feet	6
Clay, impure.....		3
Coal, good.....		4
Shale, local.....		$\frac{1}{2}$
Coal, good.....		2
Clay, plastic, siliceous.....	2	0
Shale and covered.....	35	0
Limestone, <i>Fanport</i>	3	0

Along the ridges in the southern part of Section 24 and in the northern part of Section 25, the member is regularly present but is less than 2 feet thick. It lies approximately 825 feet above tide. Little improvement was evident in sections 26 and 27. On the high ridge in the east central part of Section 28 the member was formerly mined by drifting by the McArthur Brick Company for ceramic fuel. The usual structure of the bed is lower bench of coal, 10 inches; lower parting, 1 inch; middle bench of coal, 1 feet 2 inches; upper parting, 3 inches; and upper bench of coal, somewhat bony, 1 foot 6 inches. The altitude of the bed is 900 feet; and its position is 33 feet above the Lower

Kittanning coal, 73 feet above the Vanport limestone, and 79 feet above the Clarion coal. The quality of the fuel is reported to be very good. The coal is overlain by shale which in turn is covered by sandstone, a condition found at many places in Vinton County.

Wilkesville Township.—Through lack of development and many wants the Middle Kittanning coal in Wilkesville Township is of trifling value as a source of fuel. The average thickness of the bed is less than 1 foot and the maximum measurement scarcely more than 2 feet. It is widely distributed, however, being present locally along all the larger streams in the entire township. What little mining is done is confined to stripping the coal along stream beds.

Along the abandoned road in the northwestern part of Section 12, about 1 foot 7 inches of weathered coal was found on this horizon at an altitude of 691 feet. The bed is thin along Raccoon Creek in the vicinity of Hawk and along Rockcamp Run in sections 30 and 36. In the west central part of Section 29 the member is reported to be about 1 foot thick and somewhat shaly in character. It lies 720 feet above tide. In the central part of the township the main features of the Middle Kittanning member are as shown in the record given below and which was taken at the road forks in the southeastern part of Section 21:

	Ft.	In.
Sandstone, massive, soft.....	30	0
Shale, gray, siliceous.....	7	0
Shale, dark, carbonaceous.....	3	0
Coal, shaly.....	} <i>Middle Kittanning</i> , altitude 712 feet	4½
Clay, impure.....		1
Coal, shaly.....		2½
Clay, hard, siliceous.....	1	0
Shale and shaly sandstone.....	14	0
Clay, part covered, plastic, <i>Oak Hill</i>	4	0
Sandstone, soft.....	13	0

Although in such a weakened condition the Middle Kittanning member at this place yet bears some structural features common to the great bed in the Hocking Valley field of Perry, Hocking, and Athens counties. The stratum is similar except that the upper bench of coal has passed into dark, carbonaceous shale.

Economic value

In Vinton County the field of Middle Kittanning coal with sufficient thickness for regular drift mining is not large, yet it is of great economic importance to the region. It is capable of furnishing much fuel for the support of industries and of the inhabitants thus attracted. The largest body of good coal lies in Brown Township where the total

area is 19.24 square miles and the minable area, after deducting for weathered coal along the outcrop and for that now removed by mining, is at least 15 square miles. The average thickness of clean coal in the middle and lower benches alone is 2 feet 9 inches. The roof is such that a yield of at least 70 per cent should be obtained. On this basis the quantity of fuel available is 33,264,000 tons. Further, in more than one-half the field the upper bench of coal, with a mean thickness of 8 inches, is of such quality that it may be used for general purposes. The additional yield for this coal bench is 4,032,000 tons of fuel. The total reserve of coal in Brown Township is thus nearly 37,296,000 tons which if locally used is capable of much development.

Aside from that in Brown Township, large quantities of fuel are yet available in adjacent parts of Athens County to the east. In eastern Madison and in Knox townships of Vinton County also is an area approximating 25 square miles in extent in which the Middle Kittanning coal has an average thickness of 2 feet 3 inches, exclusive of partings and bone. Although this is too thin to be mined in a large way, yet it may be drawn upon very satisfactorily for local, domestic purposes. The deposits in Elk, Vinton, Clinton, and Wilkesville townships are of no general importance.

In kind the Middle Kittanning is an ordinary bituminous coal common to this part of the great Appalachian field. It may be described also as a high volatile, free-burning fuel with fair heating qualities. It ignites readily, swells slightly in burning, produces some soot, and leaves a gray ash. It is always distinctly laminated through changes in the character of the coal itself and through the presence of fine laminae of mineral charcoal. The coal in the lower bench has fair cementing qualities, and that in the middle bench cokes slightly. The contents of sulphur and ash, however, prevent its use for making coke for metallurgical purposes. The lustre of the coal is rather dull owing to the presence of the mineral charcoal. The character of the fuel is much the same throughout the entire county field except where the bed is thin. In order to show the quality of the Middle Kittanning coal in the Brown Township field, four samples were taken for testing. These were all cut according to the specifications of the Federal Government except that the channels were made larger, that is, 4 inches deep and 12 inches wide. The sampling was done, in 1925, by P. R. Maxey and T. R. Meyers and the chemical work by Prof. D. J. Demorest of the Ohio State University.

The Middle Kittanning coal was sampled at the "Horse Cave," which is located on the east side and near the mouth of Wildcat Hollow about one mile west of Hope Furnace. It is on land of the Ohio Mineral Company. The bed was channelled in a small drift under the overhanging ledge and about 50 feet from the outcrop. The mine

was dry. The chemical data are given below. (See page 318 for section.)

<i>Ultimate analysis</i>			<i>Proximate analysis</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	68.68	74.51	Moisture.....	7.83	.00
Hydrogen.....	5.74	5.28	Volatile matter.....	41.71	45.25
Oxygen.....	15.66	9.44	Fixed carbon.....	44.73	48.53
Nitrogen.....	1.53	1.66	Ash.....	5.73	6.22
Sulphur.....	2.66	2.89			
Ash.....	5.73	6.22			
				100.00	100.00
	100.00	100.00			

		As received	Moisture free
Heating value....	{Calories	6,779	7,355
	{B. t. u.	12,202	13,239
Fusion of ash....	{Incipient	1,309°C.	or 2,388°F.
	{Complete	1,359°C.	or 2,478°F.

In a small opening at the head of the west fork of Wildcat Hollow on land of G. P. Drayer, a sample of Middle Kittanning coal was taken under favorable conditions. The results are given below. (See page 317 for section.)

<i>Ultimate analysis</i>			<i>Proximate analysis</i>		
	As received	Moisture free		As received	Moisture free
Carbon.....	64.56	71.65	Moisture.....	9.89	.00
Hydrogen.....	5.59	4.98	Volatile matter.....	38.14	42.32
Oxygen.....	16.74	8.81	Fixed carbon.....	43.58	48.36
Nitrogen.....	1.47	1.63	Ash.....	8.39	9.32
Sulphur.....	3.25	3.61			
Ash.....	8.39	9.32			
				100.00	100.00
	100.00	100.00			

		As received	Moisture free
Heating value....	{Calories	6,387	7,088
	{B. t. u.	11,496	12,758
Fusion of ash....	{Incipient	1,319°C.	2,406°F.
	{Complete	1,359°C.	2,478°F.

A representative sample was also taken at the mine of J. V. Hull in the east central part of Section 11, Brown Township. The data obtained from this follows:

Ultimate analysis

	As received	Moisture free
Carbon.....	65.42	71.36
Hydrogen.....	5.53	5.03
Oxygen.....	15.59	8.93
Nitrogen.....	1.38	1.50
Sulphur.....	3.38	3.69
Ash.....	8.70	9.49
	100.00	100.00

Proximate analysis

	As received	Moisture free
Moisture.....	8.32	.00
Volatile matter.....	39.46	43.04
Fixed carbon.....	43.52	47.47
Ash.....	8.70	9.49
	100.00	100.00

		As received	Moisture free
Heating value....	{ Calories	6,502	7,092
	{ B. t. u.	11,704	12,766
Fusion of ash....	{ Incipient	1,319°C.	or 2,406°F.
	{ Complete	1,376°C.	or 2,509°F.

In a small drift mine on land of A. E. Kennard located near Moonville in Section 7, the bed was sampled in the usual manner where the coal was bright and solid. The chemical results are given below. (For section of bed see page 320.)

Ultimate analysis

	As received	Moisture free
Carbon.....	62.97	68.88
Hydrogen.....	5.55	5.03
Oxygen.....	15.55	8.67
Nitrogen.....	1.33	1.45
Sulphur.....	4.07	4.45
Ash.....	10.53	11.52
	100.00	100.00

Proximate analysis

	As received	Moisture free
Moisture.....	8.58	.00
Volatile matter.....	40.53	44.33
Fixed carbon.....	40.36	44.15
Ash.....	10.53	11.52
	100.00	100.00

		As received	Moisture free
Heating value....	{ Calories	6,322	6,915
	{ B. t. u.	11,379	12,447
Fusion of ash....	{ Incipient	1,319°C.	or 2,406°F.
	{ Complete	1,376°C.	or 2,509°F.

The Middle Kittanning coal in Vinton County is a satisfactory fuel for most purposes. Its heating value as mined is nearly 6,500 calories or 11,700 B. t. u. The mean content of ash is 8.34 per cent and that of sulphur 3.34 per cent. As the ash has a fusion point of nearly 2,500° F., it is sufficiently refractory to prevent clinkering under ordinary conditions of firing. This coal is high in volatile matter, hence it burns freely with a long flame. It is useful for general heating

purposes, for steam generation, for burning ceramic products other than those influenced by sulphur, and for making artificial gas.

With reference to the roof and floor, the mining conditions of the Middle Kittanning coal in Vinton County are good throughout the entire field. The roof is either a massive sandstone or a siliceous shale with excellent strength and durability. The floor is everywhere a compact, siliceous clay which supports the weight above with little or no deformation. The two partings are objectionable in that they make the fuel dirty. Where thin the upper bench of coal is very shaly and pyritiferous. Through the oxidation of the pyrite the stratum acts as a "draw slate" and must be removed in mining. The bed is broken by joint planes into rectangular blocks, which structure aids in mining. The coal mines in rather large lumps if undercut before shooting. The lumps are somewhat fragile and do not withstand handling well. On weathering this fuel slakes little but is soon discolored by the oxidation of the pyrite and by whitewashing from the clays of the partings.

The clay associated with the Middle Kittanning coal in Vinton County has no ceramic value as it is shaly in character, high in fluxes, and low in refractory qualities. The average thickness of the bed is not more than 2 feet.

LOWER FREEPORT SANDSTONE

Stratigraphy and extent

The stratigraphic position of the Lower Freeport sandstone is normally between the Middle Kittanning coal and the Lower Freeport limestone, taking up only a part of this interval. In many places, however, it coalesces with the Upper Freeport sandstone above and with the Kittanning sandstone below with the resultant disappearance of several coal, clay, limestone, and ore beds from this part of the geological column. The areal distribution, physical features, and contact relations indicate that many sandstones of this character in the coal formations are channel deposits laid down along the lines of circulation of the water in the shallow basins then existing.

In Vinton County the Lower Freeport sandstone is a rather persistent bed in Brown, Knox, Madison, Vinton, and Wilkesville townships, where it lies on or not far above the Middle Kittanning coal. In parts of the area it so unites with the Upper Freeport sandstone as to appear as one continuous deposit. No sharp line of demarcation is evident. The member varies from 5 to 50 feet in thickness. A few sections will suffice to show the general stratigraphic relations

of the Lower Freeport sandstone to other members in the upper part of the Allegheny formation. Along the road leading from Sandy Run to the ridge north in the central part of Section 11, Brown Township, the following rocks were exposed:

	Ft.	In.
Coal blossom, <i>Mason</i>		6
Shale and covered.....	9	0
Sandstone, shaly.....	10	0
Shale and covered.....	21	0
Clay shale, part red, horizon of the <i>Upper Freeport</i> coal.....	10	0
Shale, yellowish.....	14	0
Clay, flint, impure.....	9	0
Clay, plastic, impure.....		
} <i>Bolivar</i>		
Shale, yellowish, siliceous.....	16	0
Shale, yellowish, siliceous.....	9	0
Coal smut, <i>Lower Freeport</i>		1
Clay, plastic, impure.....	8	0
Limestone, nodular, yellowish, <i>Lower Freeport</i>		6
Clay, with limestone and ore nodules.....	9	6
Shale, siliceous.....	11	0
Clay, flint, and covered.....	9	0
Sandstone, soft, massive, <i>Lower Freeport</i>	36	0
Coal and partings, <i>Middle Kittanning</i> , altitude 804 feet.....	3	10

The Lower Freeport sandstone forms the roof of the Middle Kittanning coal in most of Brown Township. The disconformity at the base is slight but sharply defined. This is equally true where shale intervenes between the sandstone and coal. The sandstone weathers readily, and in few places forms cliffs of large dimension; but it is sufficiently resistant to give rise to steep bluffs along the hillsides. Conditions are much the same in Knox, Madison, Vinton, and Wilkesville townships. Locally the Lower Freeport sandstone coalesces with the Upper Freeport member forming deposits more than 80 feet thick. The following record, taken along the road in the northeastern part of Section 18, Wilkesville Township, shows the member with good development in the southern part of the county:

	Ft.	In.
Sandstone and covered, <i>Upper Mahoning</i>	31	0
Shale, siliceous, part covered.....	13	0
Clay shale, red, part covered.....	16	0
Limestone, nodular, yellow to gray, <i>Mahoning</i>		8
Shale and covered.....	8	4
Covered, place of <i>Upper Freeport</i> coal.....	4	0
Limestone, nodular, yellow to gray, <i>Upper Freeport</i>	1	0
Shale and shaly sandstone.....	24	0
Sandstone, massive, basal portion coarse-grained, <i>Upper Freeport</i>	44	0
Shale, gray.....	9	0
Coal, <i>Lower Freeport</i>		5
Shale, gray.....	6	7
Sandstone, massive, soft, <i>Lower Freeport</i>	50	0
Covered, place of <i>Middle Kittanning</i> coal.....	5	0

The Lower Freeport sandstone, with some interruption, continues southward through Gallia and Lawrence counties to the Ohio River. Its stratigraphic relations and lithologic features are not far different throughout the entire field in southern Ohio.

Economic value

The Lower Freeport sandstone in Vinton County is of little economic interest as it has not been serviceable except in minor ways. It is loosely bonded with clay matter and iron oxides as the chief cementing components. The freshly quarried stone varies from light gray to buff in color. The particles are largely quartz sand and mica flakes the grain size of which is from fine to medium coarse. This sandstone is not sufficiently weather resistant for a satisfactory building stone and is far too impure for glass making. It may have some value for a molding sand if properly crushed and sized. The bed has not been worked at any place in Vinton County.

LOWER FREEPORT LIMESTONE AND ORE

Stratigraphy, extent, and value

The Lower Freeport member in Vinton County is of no special interest as the deposits are thin, uncertain, and impure. Even where present the stratum is usually represented by nodules of ferruginous limestone and calcareous ore which are bedded in clay and lie from 2 to 10 feet below the Lower Freeport coal. The material bears only a scanty fresh water fauna, mostly of diminutive forms. Some attention is due this member for the reason that it is the first limestone of this character with wide areal extent in the coal formations of Ohio. From the Harrison member at the base of the Pottsville formation to the Lower Freeport in the Allegheny formation all the limestones of wide distribution are marine in character; from the Lower Freeport to the Skelley limestone of the Conemaugh formation some are marine and others fresh water; and from the Skelley to the Waynesburg member of the Monongahela formation or even on through the Dunkard Series they are entirely fresh water. What is true of the limestones is also true in a broad way of the shales and sandstones in these divisions of the geological column; as is denoted not only by changes in the life that flourished but by other modifications such as color, composition, and depositive features. The Lower Freeport limestone was formed in a fresh water swamp of wide distribution, but in its conditions varied greatly, thus giving rise to deposits without close concordance.

In Vinton County, in Brown, Madison, Knox, Vinton, and Wilkesville townships, the Lower Freeport member is present with very patchy development. On account of its impoverished character it will be treated briefly. In Brown Township such deposits are locally present over nearly the entire area but consist largely of ore and limestone nodules in the basal portion of the Lower Freeport clay. No regularly bedded limestone was observed. In Madison Township conditions are not far different. The position of the Lower Freeport member in the column is shown in the following record taken along the abandoned road in the southwestern part of Section 30:

	Ft.	In.
Shale and covered.....	2	0
Allegheny formation.		
Clay, light to pink, <i>Upper Freeport</i> , much weathered....	5	0
Clay shale, with nodules of calcareous and ferruginous matter. <i>Upper Freeport</i> limestone horizon.....	2	0
Shale, yellow, parts covered.....	13	0
Clay, poorly exposed, <i>Bolivar</i>	2	0
Shale and covered.....	15	0
Shale and shaly sandstone, parts covered.....	22	0
Clay, plastic, impure, <i>Lower Freeport</i>	5	0
Clay with lime and ore balls, <i>Lower Freeport</i> limestone horizon.....	1	0
Shale, gray, argillaceous.....	5	0
Sandstone, massive, soft.....	36	0
Covered.....	8	0
Coal blossom, <i>Middle Kittanning</i>	1	0
Clay, light, plastic.....	1	0
Shale, siliceous.....	16	0
Clay, light, impure, <i>Oak Hill</i>	3	0
Shale, gray, siliceous.....	16	0
Coal, weathered, <i>Lower Kittanning</i>	2	0
Clay, light, plastic.....	7	0
Sandstone, massive, soft.....	34	0
Shale, gray, siliceous.....	6	0
Shale, gray, and covered.....	5	0
Shale, dark, carbonaceous.....	5	0
Covered.....	11	0
Shale, black.....	2	7
Coal blossom, <i>Clarion</i>	2	0
Clay, plastic.....	3	5
Clay, plastic, light.....	3	0
Sandstone, shaly, argillaceous.....		4
Sandstone, shaly, ferruginous.....		4
Shale, gray.....	3	0
Ore, kidney.....		2
Shale, gray.....	12	8
Shale, bluish gray.....	4	8
Shale, gray, very fossiliferous, <i>Putnam Hill</i>	1	9
Coal, good.....	1	0
Coal, bony.....		6

} *Brookville*

Pottsville formation.	Ft.	In.
Clay, light, plastic.....	2	6
Shale, gray.....	6	3
Shale, dark, <i>Tionesta</i> coal horizon.....		4
Clay, light, plastic.....	1	8

In Knox Township little of interest was observed with reference to the Lower Freeport limestone. In parts of the area the coal, clay, and limestone on this horizon are replaced by the Upper Freeport sandstone. Such conditions exist also in most of Vinton and Wilkesville townships. Where present the horizon is marked only by nodular matter in clay.

The Lower Freeport member in Vinton County has no value economically. Where much weathered along the outcrop the limestone is replaced by iron oxides, thus making it a lean ore. This was worked to a small extent at a few places in Brown and Madison townships for the charcoal furnaces. As a source of lime the deposits are entirely unsatisfactory.

LOWER FREEPORT OR No. 6a COAL

Stratigraphy, extent, and value

The Lower Freeport coal belongs about midway in the interval between the Middle Kittanning and the Upper Freeport members. Although widely distributed in Ohio it appears with fair development only in small areas, the most valuable of which are in eastern Ohio in Columbiana and Jefferson counties. Usually the horizon is marked by not more than a few inches of coal or by a mere soot streak of organic matter.

In Vinton County the Lower Freeport coal is poorly represented, the average thickness being only a few inches and the maximum measurement approximately 1 foot. From many observations its position is normally 56 feet above the Middle Kittanning coal and 42 feet below the Upper Freeport coal. The member is present in some condition of development in parts of Brown, Madison, Knox, Vinton, and Wilkesville townships; but it has not been mined at any place within the area. The following record taken along the road in Section 6, Brown Township, is representative of the thicker deposits in the northern part of the county:

	Ft.	In.
Sandstone, massive, soft, <i>Upper and Lower Mahoning</i>	72	0
Covered, horizon of <i>Upper Freeport</i> coal.....	6	0
Shale and covered	2	0
Clay, flint, gray, siliceous.....	2	6
Sandstone, nodular, calcareous, shaly.....	1	4
Clay, flint, light gray, siliceous.....	2	0
Clay, plastic, part covered.....	3	0

Bolivar

	Ft.	In.
Sandstone, hard, blocky, ferruginous.....	1	11
Shale, blue, very siliceous.....	9	0
Limestone, fresh water, local.....		2
Clay, dark, plastic, with limestone nodules.....	4	0
Sandstone, shaly.....	18	0
Shale, gray.....	2	0
Coal, bony.....	} <i>Lower Freeport</i>	1
Shale, soft.....		3
Coal, bony.....		8
Clay, plastic, dark gray, impure.....	4	4
Clay, light, plastic, with many small ore nodules.....	} <i>Lower Freeport</i>	0
Clay, dark, plastic.....		10
Clay, light, plastic.....		0
Shale and covered.....	5	0

Where observed, in Madison Township, seldom more than a soot streak of coaly matter marks the horizon. The associated clay, however, is often very thick but is always impregnated with such quantities of calcium and iron compounds as to render it unfit for ceramic purposes. Neither the coal nor clay improves in Knox Township. In some areas these beds give way to massive sandstone. Near Radcliff in Section 26, Vinton Township, the following geological relations were found:

	Ft.	In.
Sandstone, coarse-grained, light, <i>Lower Mahoning</i>	10	0
Shale and covered, horizon of <i>Upper Freeport</i> coal.....	4	8
Ore and limestone, <i>Upper Freeport</i>		4
Shale and covered.....	10	0
Sandstone, parts covered.....	29	0
Coal blossom, <i>Lower Freeport</i>	1	0
Shale and covered.....	14	0
Sandstone and covered.....	23	0
Coal blossom, <i>Middle Kittanning</i>		6
Clay, impure.....	1	6
Shale and covered.....	13	0
Sandstone, massive.....	71	0
Limestone, <i>Vanport</i>	2	0
Shale and covered.....	4	0
Coal blossom, <i>Clarion</i>	2	0

Except for clay and nodular limestone, the Lower Freeport horizon is scarcely discernible in Wilkesville Township. The conditions in the coal formation swamps at this time were unfavorable for the preservation of the vegetable matter growing therein. The Lower Freeport coal in Vinton County is of no value even for a local supply of fuel on account of its persistent thinness and its shaly character. The deposits are of interest largely in that they aid in the correlation of thicker lenses found elsewhere in southern Ohio with small areas

of fair quality coal in the central and the eastern parts of the State. This horizon marked either by coal, clay, limestone, or iron ore is fairly persistent across Ohio from Columbiana to Lawrence counties.

UPPER FREEPORT SANDSTONE

Stratigraphy, extent, and value

The Upper Freeport sandstone belongs in the interval between the Lower Freeport coal and the Bolivar clay. It may be absent from the section, may fill only a part of the interval, may occupy all of this space, or may expand so that it replaces overlying or underlying beds. It is usually a loosely-bonded, medium-grained sandstone, decidedly micaceous and somewhat ferruginous in character. Clay matter also forms a part of the bond. It is always cross-bedded, the planes being best marked on weathered surfaces. The color of the rock varies from light gray to brownish buff, the intensity of the shade depending on the quantity of iron compounds present and on the degree of weathering. The stratum varies in thickness from 1 to 60 feet.

In Vinton County the Upper Freeport sandstone is due above drainage in a broad belt in the eastern part, including parts or all of Brown, Madison, Knox, Vinton, and Wilkesville townships. The bed, however, lacks continuity, giving way to shales in many places. The best developed deposits are from 30 to 50 feet in thickness. It shows no unusual features of stratigraphic interest, hence it need not be treated in detail. The Upper Freeport member in this area is too loosely cemented for building stone, pulp wheels, and grindstones; too high in impurities for glass sand, cement mortars, and wall plasters; and too low in bond for a high-grade molding sand. It has not been utilized except for minor purposes at any place within the county.

BOLIVAR CLAY

Stratigraphy, extent, and value

The Bolivar clay, named from exposures near Bolivar, Westmoreland County, Pennsylvania, is an uncertain element in the Allegheny formation of Ohio as it is absent far more often than present. It is locally represented, however, along the entire outcrop from Columbiana County on the north to Lawrence County on the south. The deposits are likewise variable in thickness, in composition, and in position. The Bolivar clay belongs to a thin coal bed lying just under or not far below the Upper Freeport limestone. Where the limestone and coal are absent the Bolivar clay may coalesce with the Upper Free-

port clay, the two thus appearing as one bed. The member may be made up of plastic clay, of flint clay, or of almost any mixture of the two. In general the flint clay occurs largely in lenticular and unsymmetrically shaped bodies bedded within the plastic. The deposits vary from 1 to 15 feet in thickness.

The plastic clay is somewhat grainy in appearance, low in bonding power, commonly siliceous and micaceous in character, and more or less stained with iron oxide. It is in many places much charged with concretionary matter and pyrite crystals. The hard clay is a true flint in kind. It breaks with a distinct conchoidal fracture and weathers into angular pieces with sharp edges and corners. The texture of the material changes from fine to coarse, depending largely on the quantity and the state of division of the free silica present. The usual color is light to dark gray, but shades of pink and brown are not uncommon. It is in many places slightly laminated and often marked by blotches and narrow veins of material having a more glossy appearance than the body of the clay. Plant markings may be present in both the flint and plastic kinds.

The Bolivar clay is evidently of swamp origin. Such a derivation is indicated by its direct association with the thin bed of coal, by root impressions in the clay, by its frequent impregnation with limestone nodules, and by the general properties of the material, which are the resultant more of chemical activity than merely of mechanical separation. Although the marshy condition was widespread, the basins were more or less detached through barriers of various kinds such as land areas, bars, shoals, etc. The floor was very uneven throughout the entire field. Within the depressions much local variation existed in such essential factors, as depth of water, duration of existence as a swamp, quantity and character of sediments filtering therein, and activity and kind of reagents operative. Such changes in the kinds of clay and the thickness of the deposits are evident along the entire outcrop of the member in Ohio.

In Vinton County the Bolivar clay holds true to form in that it lacks persistency, regularity in thickness, and constancy in kind. Local deposits are present in Brown, Madison, Knox, Vinton, and Wilkesville townships. These vary in thickness from 2 to 12 feet but average nearly 6 feet. Both flint and plastic clay are represented, the latter, however, being by far the more common. The top of the clay lies from 3 to 20 feet below the Upper Freeport coal, which is the best bench for reference. The material is in many places so ferruginous that on weathering it has a pinkish or brownish tint. Locally the Bolivar member coalesces with the Upper Freeport clay with no apparent line of separation.

In Brown Township this member is present with fair regularity along the ridges in the eastern and the central parts. Along the road

that leads from Sandy Run to the ridge north in the central part of Section 11, the horizon is marked by 9 feet of flint clay underlain by 16 feet of plastic. Both materials are impure. The deposit lies 892 feet above tide and 84 feet above the Middle Kittanning coal. The member is also exposed at other places along the headwaters of Sandy Run and on the ridges in the vicinity of Hope Furnace. Some of the stratigraphic features are shown in the following record taken in the south central part of Section 7:

	Ft.	In.
Sandstone, parts covered, <i>Lower Mahoning</i>	30	0
Clay and covered, <i>Upper Freeport</i> horizon.....	5	0
Clay, with coal smut.....		1
Clay, flint, impure.....	2	0
Clay, plastic, grainy.....	5	0
} <i>Bolivar</i> , altitude 900 feet		
Shale, gray, siliceous.....	7	0
Clay, impure, with ore balls.....	5	0
Sandstone and covered, <i>Upper and Lower Freeports</i>	81	0
Clay shale.....		3
Coal, good.....	1	11
Clay shale.....		1
Coal, good.....		5
} <i>Middle Kittanning</i>		

All the high ridges in the eastern part of Madison Township contain local deposits of Bolivar clay, most of which is plastic in character. The elevation of the member is nearly 1,000 feet in Section 30; 910 feet in Section 18; 920 feet in Section 25; and 830 feet in Section 13. Where observed the deposits vary from 3 to 12 feet in thickness. The bed is due above drainage in all of Knox Township but with few exceptions it is poorly represented. Conditions are similar in eastern Vinton Township and south of this in Wilkesville Township.

The Bolivar clay in Vinton County is not recommended for use in the manufacture of ceramic products as the quality is much below the required standard. The flint clay on this horizon is very heat resistant but it is nearly always so charged with concretionary matter as to seriously impair its value for refractory products. The lack of continuity, variability in thickness, and poor mining conditions are also unfavorable for its utilization. The plastic clay associated with the flint is also high in basic fluxes, the most damaging of which are iron oxide, lime, and potash. It is grainy and plastic with poor bonding power. It fuses at a low temperature, has a short vitrification range, and has a large volume shrinkage. The body is "punky" at incipient vitrification and brittle at complete solidification. The color is usually an unattractive buff. The Bolivar clay has not been utilized at any place in Vinton County. The unnamed coal, associated with the Bolivar clay and lying below the Upper Freeport limestone, is poorly represented in this area. In many places it is absent. Commonly it consists only of a thin streak of carbonaceous matter. The maximum thickness observed is 6 inches.

UPPER FREEPORT LIMESTONE

Stratigraphy, extent, and value

The Upper Freeport limestone is of fresh water origin and like most limestones of this derivation it shows a decided lack of uniformity in continuity, thickness, composition, position, and bedding. It was not laid down as a sheet but as irregular lenses and patches. Conditions of sedimentation were thus very different in different parts of the widespread basin. This limestone is broadly distributed in Ohio, being present to some extent in every county along the outcrop from Columbiana to Lawrence. In general the deposits are far better developed in the eastern part of the State than they are in the southern part. The Upper Freeport limestone lies normally between the Bolivar clay and the Upper Freeport clay, or 3 to 10 feet below the Upper Freeport coal, which is the most prominent bench for reference. The Upper Freeport limestone belongs in the general period of inundation that gave rise to the Bolivar clay, the associated unnamed coal, the Upper Freeport clay, and the Upper Freeport coal.

In Vinton County the horizon of this member is only occasionally marked in a definite way. The deposits consist most largely of nodular matter in clay. These concretions vary in diameter from 1 inch or less to 1 foot or more and in composition from rather pure calcium carbonate to calcareous and argillaceous iron ore. Where definitely bedded the stratum is not often more than 1 foot thick. In places the material is disseminated throughout the body of the Upper Freeport and Bolivar clays in such a way as to lose its identity as an individual limestone member. It appears more as impurities in the clays. The Upper Freeport limestone is present in some state of development in Vinton County in local areas in Brown, Madison, Knox, Vinton, and Wilkesville townships. As it is of small interest stratigraphically and of no value economically, the member will not be treated further.

UPPER FREEPORT OR No. 7 COAL

Stratigraphy and extent

The Upper Freeport or No. 7 coal is the youngest member in the Allegheny formation, the shale or sandstone overlying it being of Conemaugh age. It is another of the inconstant beds with a wide areal range on this general horizon. The member, however, is an important source of fuel in large fields in western Pennsylvania and in eastern and central Ohio. In Ohio it is exceeded in value only by the Middle Kittanning and the Pittsburgh members. The bed is mined most actively in Columbiana, Carroll, Harrison, and Guernsey counties.

From the Cambridge field southward to the Ohio River in Lawrence County only small bodies of coal with sufficient thickness for drift mining are found along the belt of outcrop. In large areas the horizon is marked only by a soot streak or by its associated clay. The absence of coal is due mainly to lack of deposition and not to replacement. In the main fields in eastern Ohio the thickness of the bed is between 3 and 7 feet.

In Vinton County the outcrop of the member is confined to parts of Brown, Madison, Knox, Vinton, and Wilkesville townships. It is wanting or very thin, however, except in small areas in sections 27, 28, 29, and 30, Knox Township, and in sections 32 and 33, Wilkesville Township, where it is mined in a small way for local fuel. The position of the Upper Freeport coal is normally 98 feet above the Middle Kittanning coal and an equal distance below the upper bench of the Brush Creek limestone, which are the most reliable beds for reference. Where well developed the stratum may be without partings or it may be one or more thin layers of clay or bony shale.

Brown Township.—No coal of value was found on the Upper Freeport horizon in Brown Township, although the member is due along the ridges in most of the area. The elevation of the bed is 1,000 feet in the north central part of Section 24; 910 feet in the central part of Section 6; 1,000 feet in the southern part of Section 32; and 865 feet in the northeastern part of Section 1.

Madison Township.—The Upper Freeport coal is likewise greatly impoverished in Madison Township, appearing more often as a mere soot streak than as a bed of coal. A composite section, taken in the central part of Section 16 and given below, shows some of the main stratigraphic features:

	Ft.	In.
Flint, black, fossiliferous, <i>Upper Brush Creek</i> bed.....	2	2
Shale, sandstone, and covered.....	52	0
Coal blossom, <i>Mason</i>	1	0
Shale and covered.....	12	0
Clay shale with small limestone nodules, horizon of <i>Mahoning</i> coal.....	10	0
Shale, drab.....	4	0
Sandstone, part shaly, <i>Lower Mahoning</i>	22	0
Coal smut, <i>Upper Freeport</i>		1
Clay, plastic, and flint.....	6	6
Ore and limestone in nodular form, <i>Upper Freeport</i>		6
Shale and covered.....	26	0
Sandstone, massive.....	46	0
Shale, gray, siliceous.....	5	0
Coal, good, <i>Middle Kittanning</i>	1	10

Knox Township.—In Knox Township the Upper Freeport member so expands, locally, in sections 30 and 27, that it is mined by drift-

ing for a part of the fuel supply. At the mine of Wade Heckert in the southeastern corner of Section 30, the following measurements were secured:

	Ft.	In.
Sandstone, massive, <i>Lower Mahoning</i>	20	0
Shale and covered.....	5	0
Shale, gray.....	3	0
Coal, bony.....		3
Coal, fair.....	1	$\frac{1}{2}$
Clay shale, irregular....		$1\frac{1}{2}$
Coal, fair.....		6
Clay, impure.....	3	0

The coal in both benches is high in sulphur in the form of pyrite which is disseminated in sheets and flakes throughout the mass. That in the upper bench is the most impure. In parts of the mine the member is reported to thicken to 4 feet or more. The overlying shale is somewhat tender, thus forming a poor roof. The position of the Upper Freeport coal here is about 75 feet below the lower bed of the Brush Creek limestone. On the property of J. A. Trout in the south central part of Section 30, Knox Township, a small mine was also in operation when the region was visited (1924). The record obtained is given below:

	Ft.	In.
Sandstone, massive, <i>Lower Mahoning</i>	30	0
Shale, soft, irregular.....	3	6
Coal, fair.....	1	7
Clay shale.....	1	$3\frac{1}{2}$
Coal, fair.....		7

The thickness of the bed varies from 1 to 4 feet but averages about as shown above. This coal is present also in the northeastern part of Section 29 where, however, it is reported to be very unsteady. No deposits of good coal were found on the Upper Freeport horizon in the northwestern part of the township. It is thin through lack of deposition. The Upper Freeport coal lies about 870 feet above tide in the central part of Section 12. The other area in Knox Township in which this coal is mined for local use is along the stream in the central part of Section 27. At the drift mine of D. S. Roberts the following record was taken:

	Ft.	In.
Sandstone and shale.....	14	0
Limestone and covered, <i>Brush Creek</i>	15	0
Shale, siliceous.....	10	0
Sandstone, shaly.....	7	0
Sandstone, massive, soft, <i>Upper and Lower Mahoning</i>	68	0
Coal.....	1	11
Clay, impure.....	1	3
Coal.....		9

The coal is high in sulphur but otherwise of fair quality. The upper bench is somewhat irregular owing to the influence of the overlying sandstone. The roof is strong and durable. Near by in the central part of Section 27, E. M. and Clyde McVey also mine the Upper Freeport member for the local trade. The lower bench of coal measures 1 foot 8 inches, the parting $1\frac{1}{2}$ inches, and the upper bench of coal 1 foot 10 inches. The coal is high in pyrite, which is distributed throughout the body of the fuel in the form of thin lenses and flakes. The roof is massive sandstone. Formerly small mines were also operated on adjacent lands in this locality. The bed varies from 1 to more than 4 feet in thickness. Along a small southern tributary of Onion Creek in the northeastern part of Section 28, the Upper Freeport coal is worked for household fuel on the property of W. M. Zimmerman. The deposit is unsteady, varying in thickness from 1 foot 4 inches to 3 feet. In the southern part of Knox Township the member is generally wanting or thin. Its altitude is 690 feet in the southeastern part of Section 25 and 820 in the southwestern part of Section 7.

Vinton Township.—In Vinton Township the Upper Freeport horizon is present well above the valley floors in the eastern part and on the high knobs of the ridges in the western part. In most of the field the bed fails to be a well-defined stratum. The thickest deposit observed is 1 foot 8 inches thick and is located on the land of J. W. Canode in the southeastern part of Section 3. The coal is directly overlain by massive sandstone and its position is 790 feet above tide.

Wilkesville Township.—Except for a few small bodies of good coal the Upper Freeport member is of no value as a source of fuel in Wilkesville Township. The deposits of most importance are present along the main ridge in the southwestern part where it is mined in a desultory way for local needs. On land of the Superior Colliery Company in the west central part of Section 33, the Upper Freeport coal has been prospected by a drift mine. The bed varies from 3 to 5 feet in thickness but averages nearly 4 feet. The irregularity is due to erosion of the upper surface, which is thus very uneven in outline. The roof is sandstone with thin bands of coaly matter interbedded in the basal portion. No clay partings and few bony layers are evident in the coal stratum. The deposit lies 870 feet above tide. The geological relations of the Upper Freeport coal to other members lower in the Allegheny formation are well shown in the following record taken in the southeastern part of Section 33:

Conemaugh formation	Ft.	In.
Clay shales, pink, horizon of <i>Mahoning</i> coal.....	6	0
Shale, gray.....	4	0
Shale, light, siliceous.....	2	0
Shale, gray.....	11	0

Allegheny formation	Ft.	In.
Coal blossom, <i>Upper Freeport</i>	3	0
Clay, impure	3	0
Sandstone, coarse-grained, light colored	9	0
Shale, gray, siliceous	4	0
Coal blossom		2
Clay, impure, <i>Bolivar</i> horizon		10
Shales, gray, sandy	8	0
Ore, nodular, in shale	1	0
Clay shales	2	0
Sandstone, coarse-grained, micaceous	7	0
Clay shale, light	5	0
Clay shales with thin coal bands	1	0
Shales, gray, siliceous	13	0
Clay shale	1	0
Clay shale with thin coal bands	1	0
Clay shale	4	9
Clay, with thin coal bands, <i>Lower Freeport</i>		3
Clay, dark, plastic	1	0
Covered	14	0
Shales, gray, siliceous	11	0
Ore, nodular, irregular		6
Sandstone, shaly	4	6
Covered	5	0
Coal blossom, <i>Middle Kittanning</i>	1	0
Sandstone and covered	31	0
Coal blossom, <i>Lower Kittanning</i>	1	0
Clay, shale, and covered	25	0
Limestone, <i>Vanport</i>	7	0
Coal and partings, <i>Clarion</i>	4	3

In this general locality the Upper Freeport member lies approximately 60 feet below the Mason coal and 100 feet below the upper bench of the Brush Creek limestone, which are represented only on a few of the outstanding knobs. The thickest and purest body of Upper Freeport coal in Vinton County is present on the ridge in the northeastern part of Section 32. In a drift mine on the property of Curtis Zinn the following measurements were obtained:

	Ft.	In.
Shale, siliceous, gray	5	0
Shale and bony coal	1	0
Coal, good, without } <i>Upper Freeport</i> , altitude 805 feet	5	1
partings		
Coal, bony		2

The fuel in the main bed is of excellent quality, being clean, bright, and solid. In parts of the old mine near by, the stratum expands to as much as 6 feet. Near the Cooney School in the southeastern part of Section 28, the Upper Freeport member has been opened in a few places. Its thickness is reported to be from 1 to 4 feet. In the re-

mainder of Wilkesville Township, outcrop exposures indicate that the Upper Freeport coal is everywhere thin excepting possibly in the northeastern corner. Just east of the county line, in the southwestern part of Section 36, Salem Township, Meigs County, it has been opened at a few places and worked for local use. The record given below was taken on the property of Ezra Knapp:

	Ft.	In.
Limestone, <i>Cambridge</i>	1	0
Shale and covered	27	6
Limestone, fossiliferous, upper bench of <i>Brush Creek</i>	1	6
Shale, gray	19	0
Coal blossom, <i>Brush Creek</i>		6
Shale and shaly sandstone, gray	19	6
Coal blossom, <i>Mason</i>	1	0
Clay shale, red, parts covered	20	0
Sandstone, massive, <i>Lower Mahoning</i>	32	0
Shale, gray, tender, variable in thickness.....	2	0
Coal, good.....	2	2
Shale, dark		$\frac{1}{4}$
Coal, good.....		$2\frac{1}{2}$
Shale, dark	} <i>Upper Freeport</i> , altitude 720 feet	$\frac{1}{2}$
Coal, good.....		$2\frac{1}{2}$
Shale, argillaceous.....		$\frac{1}{2}$
Coal, good.....		3

In this locality the bed is reported to thicken to 4 feet on the land of Bert Phillips. The coal is fairly high in sulphur but otherwise of fair quality if mined in a clean manner. Where observed south of Wilkesville the stratum is shaly in character, and only a few inches in thickness.

Economic value

The Upper Freeport member in Vinton County varies widely not only in thickness and in structure but also in composition. This coal in the few well developed deposits present in Knox Township is exceptionally high in sulphur, held in the form of ferrous disulphide or the mineral pyrite, which occurs in thin, irregular lenses lying parallel to the bedding planes, in flakes along joints and fractures, and in small crystals disseminated throughout the mass. Through this impurity the ash under oxidizing conditions burns to a deep red, spongy mass, and under reducing conditions fuses at low temperatures to a hard, nearly black clinker. Aside from the iron constituents the ash is not large. On exposure to the weather the coal whitewashes badly owing to the oxidation of the pyrite to ferrous sulphate. This fuel is of such poor quality that it is mined only for a small local trade. In comparison with this the other body of minable Upper Freeport coal in southwestern Wilkesville Township is much above the average

in purity. It is low in ash and sulphur, breaks with a clean fracture, and has a bright color. This fuel is held in high esteem for domestic purposes and for steam generation. All the mines working the Upper Freeport member in Vinton County are small wagon operations, employing only a few men. Where the coal is overlain by sandstone the roof is very strong and durable, but where shale intervenes it is unsafe unless properly timbered. This member in Vinton County is a reserve of only local importance.

CONEMAUGH FORMATION

The Conemaugh formation, named in 1875 by Franklin Platt, includes all the strata from the top of the Upper Freeport coal to the base of the Pittsburgh coal. These rocks are shales of diverse textures and colors; sandstones with many modifications; limestones of marine, brackish, and fresh water origin; coals mostly thin and impure; clays usually calcareous and ferruginous in composition; conglomerate originating from various hard materials and from both local and distant sources; and iron ores either disseminated through the shales in nodular form or occurring in thin beds with small lateral extent. Owing to the pronounced impoverishment of the coal beds the formation was formerly known as the Lower Barren Coal Measures. This group of rocks is characterized also by the conspicuous change in color of some of the strata, especially the shales, from shades of gray which are prevalent with the rocks in the Pottsville and Allegheny formations below to shades of red, buff, and brown which are common with those in the Monongahela, Washington, and Green formations still higher in the geological column. Through the faunal remains the limestones in the Conemaugh formation also show a difference in the mode of origin and represent in a general way the transitional stage in the Pennsylvanian system from sediments laid down largely in the sea to those deposited entirely in fresh water basins. As far as known at present the Skelley limestone of middle Conemaugh age represents the last invasion of the sea in the great Appalachian coal formation trough. The deposition of fresh water limestone, however, began in middle Allegheny time and that of coal and clay, assigned to swamp origin, began with the inauguration of the Pottsville. The evidence afforded by the rocks thus indicates that this great basin lying between old Appalachia on the east and the Cincinnati uplift on the west was flooded with salt water except for short but frequent periods during Pottsville and early Allegheny time, was gradually being so filled with sediments that the sea invasions were of short duration during late Allegheny and early Conemaugh time, and was so elevated that the deposition was entirely continental in character during late Conemaugh

and Monongahela time, and even on through the succeeding Washington and Green ages of the Dunkard epoch. The Conemaugh formation thickens to the eastward showing that the sediments came from that direction, probably from old Appalachia. The usual measurement of this division of rocks is nearly 350 feet in southern Ohio, about 475 feet in the eastern part of the State, and nearly 800 feet in the vicinity of Charleston, West Virginia. On the whole the Conemaugh formation in Ohio is poor in mineral resources as it has provided only small quantities of coal for general use, of clays and shales for ceramic industries, of iron ore for metallurgical operations, of limestone for various needs, and of sandstones for building and abrasive purposes. Its deeply buried rocks, however, have been the source of considerable oil and gas.

In Vinton County only the lower portion of the Conemaugh formation is represented, as the section begins with the Mahoning sandstone and ends with the Cambridge limestone. The maximum thickness of such rocks in this area is not more than 150 feet which is less than half the total thickness of the formation in adjacent areas to the east and south. In general the individual beds are not especially well developed, are usually lacking in persistency, and show considerable variation in character, which features make them difficult to trace across the field. The Brush Creek limestone and the Mason coal are the most distinct and therefore the safest benches for reference in stratigraphic work. In an economic way the rocks of this formation are of little interest as neither the quantity nor the quality is such as to justify their utilization. Strata of this age are present above drainage in Brown, Madison, Knox, Vinton, and Wilkesville townships.

Section of the Conemaugh rocks in Vinton County

Formation	Member	General Description	Thickness	
			Ft.	In.
Conemaugh.	Cambridge.....	Limestone, gray, fossiliferous.....		8
		Shale, gray.....	2	0
	Wilgus.....	Coal, impure, locally present.....		6
		Clay and clay shale.....	10	6
	Buffalo.....	Sandstone, locally conglomeratic, often absent.....	15	0
		Shale, gray.....	3	0

Section of the Conemaugh rocks in Vinton County—Concluded.

Formation	Member	General Description	Thickness	
			Ft.	In.
Conemaugh.. (Concluded)	Brush Creek.....	Limestone, or flint, fossiliferous.....	2	0
		Shales, part calcareous, with a few fossils.....	27	1
		Limestone or shale, very fossiliferous.		11
		Shales, clay shales, and sandstones..	23	4
	Mason.....	Coal, impure, fairly persistent.....	1	2
		Clay, light, plastic, impure.....	4	6
	Upper Mahoning.	Sandstone, only locally present.....	14	5
	Mahoning.....	Coal, very unsteady.....		3
		Clay, plastic, light to mottled, impure.....	5	0
	Mahoning.....	Limestone, light, nodular, fresh water, only locally present.....		6
	Lower Mahoning.	Sandstone, often replaced by shale..	21	6
		Total.....	132	4

LOWER MAHONING SANDSTONE

Stratigraphy, extent, and value

The position of the Lower Mahoning sandstone is in the interval between the Upper Freeport coal and the Mahoning limestone. In Vinton County the member is present only locally in the eastern part. It occurs more in the form of narrow channel deposits and irregular lenses than in that of uniform sheets of wide extent. In a few places it coalesces with the Upper Mahoning sandstone, thus forming one thick deposit with no definite line of demarcation. In many places the bed is absent from the section, its place being taken by shale. Usually the Lower Mahoning sandstone is soft and friable, ferruginous and argillaceous in character, and fine to medium in size of grain. Aside from quartz the most conspicuous mineral is muscovite in bright, splendid flakes. Weathering rapidly reduces this rock to sand.

In Brown Township the most conspicuous exposures of Lower Mahoning sandstone are in the northeastern part where the deposits vary from 10 to 40 feet in thickness. The conditions are somewhat

similar in the east central part of Madison Township along the headwaters of Wheelabout Creek. The member is more reliable and uniform in Knox Township than in any other part of Vinton County. In most of the area it lies directly on or only a few feet above the Upper Freeport coal and in places so expands that it coalesces with the Upper Mahoning sandstone, thus replacing several beds in this part of the geological column. This condition is shown in the following record taken on the hill projecting into Raccoon Valley near the boundary of sections 5 and 6:

	Ft.	In.
Sandstone, shaly, parts covered.....	20	0
Sandstone, massive, parts coarse grained, fairly weather resistant.....	87	0
<i>Upper and Lower Mahoning</i>		
Shale and covered, place of <i>Upper Freeport</i> coal at base of the overlying sandstone.....	11	0
Clay, grainy, dark, <i>Bolivar</i>	11	0
Clay, light, <i>Lower Freeport</i>	2	0
Sandstone, massive, soft.....	46	0
Covered.....	5	0
Coal blossom, <i>Middle Kittanning</i> , altitude 730 feet.....	2	0

In Vinton Township local deposits of Lower Mahoning sandstone are found along the ridges throughout the eastern and central parts. Its stratigraphic and physical features are not unusual. Although widely distributed in Wilkesville Township the member is not often well represented.

The Lower Mahoning sandstone in Vinton County is without sufficient merit to warrant its use. It is not fitted for building stone for on exposure it soon molders to a mass of sand. The rock is too impure for glass sand and too fine in grain for mortars. It may have some value for molding sand if properly ground and prepared.

MAHONING LIMESTONE

Stratigraphy and extent

The normal position of the Mahoning limestone is at the base of the Mahoning clay. It was the first deposit laid down in the fresh water swamps of this period in which clay and eventually coal were also formed. Where much impoverished the calcareous matter is frequently distributed in fine grains or small nodules throughout the body of the clay. In most of Vinton County the Mahoning limestone as a distinct bed is absent from the section. The following record

taken on the ridge in Section 12, Brown Township, is representative of the few deposits observed:

	Ft.	In.
Shale, drab.....	37	0
Limestone, blue, fossiliferous, <i>Lower Brush Creek</i>		9
Shale, dark.....		8
Coal smut.....	1	3
Clay shale, dark.....		0
Shale, carbonaceous, with thin coal bands.....		8
Clay shales, pink to buff.....		4
Coal smut, <i>Mahoning</i>	13	2
Clay, plastic.....	1	10
Limestone, impure, fresh-water, <i>Mahoning</i>		6
Shale, drab.....	3	0

Deposits somewhat similar in character were noticed in the eastern part of Vinton Township and in the northern part of Wilkesville. The limestone is occasionally replaced by impure iron ore in the nodular form. They have no value economically.

MAHONING COAL

Stratigraphy and extent

The Mahoning coal, the oldest member of this kind in the Conemaugh formation, is widely distributed in Ohio, extending with many wants and much impoverishment from Columbiana County on the north to Lawrence County on the south. It attains minable thickness only in parts of Columbiana, Jefferson, and Carroll counties where it is known locally as the "Groff," "Strip," and "Finley" bed. Elsewhere in Ohio if present the member is represented by a few inches of coal, by a mere soot streak, or by carbonaceous matter in the upper few inches of the Mahoning clay. Normally its position is about two-fifths of the way up in the interval between the Upper Freeport coal and the Brush Creek limestone.

In Vinton County the Mahoning coal is not only poorly but erratically developed. The horizon, however, is in many places marked by coaly matter in some form in parts of Brown, Madison, Knox, Vinton, and Wilkesville townships. The bed has a maximum thickness of about 6 inches and an average measurement of less than 3 inches. From a number of observations its position is 27 feet above the Upper Freeport coal, 19 feet below the Mason coal, and 43 feet below the Brush Creek limestone. The Mahoning coal is underlain by clay, known in West Virginia as the Thornton. Like the coal the clay is poor in quality as it is ferruginous and calcareous. The average thickness of the clay, however, is nearly 5 feet.

Few deposits of Mahoning coal were observed in Brown Township as the member lies near the summits of the ridges where exposures are few. The elevation of the bed is 990 feet in Section 12, and 945 feet near the head of King Hollow in Section 3. The member outcrops only on the high ridges in the eastern and central parts of Madison Township. The following record taken in the northeastern part of Section 29 shows some of the stratigraphic features:

	Ft.	In.
Flint, dark, <i>Upper Brush Creek</i> , altitude 1,050 feet.....	1	0
Shale and covered.....	19	0
Sandstone, shaly.....	7	0
Covered.....	20	0
Coal blossom, <i>Mahoning</i>		6
Clay and covered, <i>Thornton</i>	5	0
Shale and covered.....	15	0
Shale, dark, horizon of <i>Upper Freeport</i> coal.....	1	0
Clay, light, plastic.....	3	0

In most of Knox Township the Mahoning coal and clay are largely replaced by massive sandstones which make up most of the interval from the Upper Freeport coal to the Brush Creek limestone. Where present the horizon is more frequently marked by carbonaceous shale than by coal. Such deposits are present 770 feet above tide in the eastern part of Section 28, and 850 feet in the northwestern part of Section 1. Although widely distributed along the ridges in Vinton Township, the Mahoning member is present at few places as it gives way to sandstone. The stratum improves some in continuity but little in quality in Wilkesville Township where it is due above drainage in most of the area. The following record, taken along the road in the southeastern part of Section 15, shows its position with reference to other well known members:

	Ft.	In.
Coal blossom, <i>Mason</i>	1	0
Clay, pink, partly covered.....	10	0
Sandstone, soft, ferruginous.....	1	0
Clay, yellow to pink.....	7	8
Shale, coaly, <i>Mahoning</i> , altitude 786 feet.....		4
Clay, grainy, dark.....	3	0
Sandstone, massive, soft.....	26	0
Horizon of <i>Upper Freeport</i> coal.		
Clay, light to yellow, impure, <i>Upper Freeport</i>	4	0

The Mahoning coal in Vinton County is of no value as a source of fuel as the stratum in nearly all of the area is not only thin but very shaly. It is not mined even along stream beds where the overburden has been largely removed by erosion. The associated clay is poor in quality due to the high content of basic fluxes, and is not recommended for any kind of ceramic product.

UPPER MAHONING SANDSTONE

The position of the Mahoning sandstone is in the interval between the Mahoning and Mason coals. It may be absent from the section, occupy part or all of this interval, or so expand that it replaces overlying or underlying beds. In composition and texture this member is similar to the Lower Mahoning sandstone; the material forming it was evidently derived from the same source and deposited under similar conditions. The thickness of the stratum varies from 5 to 40 feet. The Upper Mahoning sandstone is not present in many places in Vinton County except in Knox Township, where it is well developed in a few areas. As the main stratigraphic features of the member are shown in sections given elsewhere, in this bulletin, the bed will not be discussed further.

MASON COAL.

Stratigraphy, extent, and value

The Mason, the second coal bed in ascending order in the Cone-maugh formation, lies normally about midway in the interval between the Mahoning coal and the lower stratum of the Brush Creek limestone. In Ohio it is best developed in the southern part of the State in Lawrence, Gallia, Meigs, and Vinton counties in which field, with the exception of the Wilgus member in Lawrence and Gallia counties, it is the thickest and most regular coal stratum in the entire formation. In central and eastern Ohio the Mason coal is poorly represented. It may be traced, however, with a degree of certainty by small lenses of coal and by deposits of impure clay. The stratum varies in character from rather pure coal through shaly coal to coaly shale. Its thickness is nowhere such as to justify drift mining on a large scale. It is worked mainly by stripping along the outcrop for small supplies of household fuel.

The Mason coal has fair continuity across the eastern part of Vinton County in eastern Brown, eastern Madison, Knox, eastern Vinton, and Wilkesville townships. It varies greatly, however, in thickness, character, and position. The range in thickness is from a few inches to more than 3 feet. The average measurement of the stratum from many determinations is nearly 1 foot 2 inches. At best this fuel is high in ash, which is distributed throughout the bed in the form of papery partings. In some localities the partings so expand in thickness and so increase in number that the bed contains more shale than coal. Normally the Mason member lies nearly 23 feet below the lower bench of the Brush Creek limestone; but this interval varies from 1 to 35 feet due to the irregularity in deposition of both the coal and the limestone.

Brown Township.—In Brown Township the deposits of Mason coal are confined to the high ridges in the eastern and central parts. The stratum is shaly and usually lies not far below the lower bench of the Brush Creek limestone. In the southeastern part of Section 18 the following record was obtained:

	Ft.	In.
Shale, drab.....	32	0
Limestone, blue, fossiliferous, lower bed of <i>Brush Creek</i>		9
Coal smut.....	} <i>Mason</i> , altitude 1,015 feet	3
Clay shale.....		8
Coal, very shaly.....		1
Clay shales.....		10
		0

Deposits similar in character were observed in sections 12, 11, 5, and 16. The horizon is also marked by shaly coal along the high ridge south of Raccoon Creek in the southeastern part of the township. The Mason coal lies 950 feet above tide in the northeastern part of Section 13 and 935 feet in the southern part of Section 1.

Madison Township.—Aside from its stratigraphic features the Mason member is of little interest in Madison Township where it is present near the summits of the high knobs and ridges. The deposits are of no value as a source of fuel on account of the shaly character. The thickness of the bed is from 6 inches to 2 feet. Its position is 10 to 25 feet below the lower layers of the Brush Creek limestone and its elevation is 1,020 feet in the northeastern part of Section 24; 925 feet in the southeastern part of Section 16; 980 feet in the central part of Section 26; and 875 feet in the east central part of Section 13.

Knox Township—Owing to the dip of the rocks to the east, the Mason coal lies not far below the summits of the ridges in the western part of Knox Township and near the valley floors in the eastern part. The bed has fair continuity and thickness but everywhere it is shaly in character. Its structure and stratigraphic relations are best shown in a record, taken just east of Knox Township near the Townhouse School and on the Floyd Foutts farm in Lee Township, Athens County. The section is given below:

	Ft.	In.
Flint, light to gray, fossiliferous, upper layer of <i>Brush Creek</i>		
limestone.....	3	2
Shale, with flint layers.....	1	0
Shale, gray.....	2	4
Shale, blue.....	2	0
Sandstone, massive.....	5	6
Shale, gray.....		3
Shale, coaly.....		2
Clay, plastic.....	3	0
Shale, gray, siliceous.....	16	7
Limestone, gray, fossiliferous, lower layer of <i>Brush Creek</i>	1	3

	Ft.	In.
Shale and covered.....	5	0
Shale, gray.....	7	1
Coal, shaly.....	} <i>Mason</i>	3
Clay shale, dark.....		6
Shale, coaly.....		5
Coal, shaly.....		7
Clay shale, dark.....		3
Shale, coaly.....		3
Coal, shaly.....		4
Clay shale, gray.....		1
Coal, fair.....		9
Clay, plastic, light to pink.....	7	0

The Mason coal has not been mined even in a small way at any place in Knox Township. It is not only high in ash but also in sulphur, held in the form of marcasite.

Vinton Township.—In Vinton Township the Mason horizon is marked more often by deposits of carbonaceous shale than by those of coal. The thickness of the bed varies from 4 inches to 2 feet. Locally the member is replaced by sandstone. With few exceptions the deposits are confined to the ridges and knobs in the eastern half of the area. Its stratigraphic relations are normal.

Wilkesville Township.—In its extension southward from Vinton into Wilkesville Township the Mason coal improves slightly in continuity and quality but little in thickness. The average measurement of the bed is not more than 1 foot. It lies from 15 to 30 feet below the lower stratum of the Brush Creek limestone and nearly an equal distance above the Mahoning coal. The member has not been mined at any place within the area.

Along the road in the central part of Section 18 about 1 foot of Mason coal was exposed at an elevation of 845 feet. It lies nearly 50 feet above the Upper Freeport coal. The member extends as far west as the southern part of Section 36 where the deposit is coal of fair quality, about 10 inches thick, and 940 feet above tide. Its relation to the Brush Creek limestone is shown in the following record taken at the forks of the road in the northwestern part of Section 29:

	Ft.	In.
Shale, drab.....	5	0
Limestone, blue, fossiliferous.....	} <i>Brush Creek</i>	10
Limestone, very sandy, blue, fossiliferous.....		
		2
Shale, gray.....	6	8
Sandstone, shaly.....	1	0
Shale, gray, siliceous.....	13	0
Covered.....	3	0
Shale and shaly sandstone.....	20	0
Coal blossom, <i>Mason</i>	1	0
Clay shales, red and light.....	22	0

Similar deposits were observed also along the ridges in sections 35 and 34. This member is regularly present in the central part of the township. Its thickness is on the average about 1 foot. The elevation of the member is 830 feet in the northeastern part of Section 17, 820 feet in the central part of Section 11, 805 feet in the southeastern part of Section 15, and 780 feet in the east central part of Section 2, south. Just south of Wilkesville in the central part of Section 3, the following record was obtained:

	Ft.	In.
Sandstone, soft, parts covered.....	38	0
Shale, gray.....	5	0
Coal, shaly, <i>Mason</i> , altitude 756 feet.....	1	1
Clay, light, plastic, impure.....	2	3
Sandstone, hard, irregular.....		8
Sandstone, argillaceous.....	1	4
Sandstone, soft, micaceous, <i>Mahoning</i>	38	0
Clay, plastic, horizon of <i>Upper Freeport</i> coal.....	2	0

East of Wilkesville in Salem Township, Meigs County, the *Mason* coal increases in regularity and thickness but becomes more shaly in character. Its position is about 55 feet below the upper stratum of the *Brush Creek* limestone and approximately 80 feet below the *Cambridge* limestone.

Economic value

At no place in Vinton County is the *Mason* coal drawn upon even for small supplies of household fuel as the bed is generally thin and impure. The average thickness of the stratum is about 1 foot and the maximum measurement nearly 3 feet. The local expansions, however, are due more to the addition of carbonaceous shale than to that of coal. Much *marcasite* is also present throughout the stratum. Prospecting has been confined to pits along the outcrop.

BRUSH CREEK LIMESTONE

Stratigraphy and extent

The *Brush Creek* limestone, named by I. C. White, in 1878, for deposits appearing on *Brush Creek*, in *Cranberry Township*, *Butler County*, *Pennsylvania*,¹ is a well recognized stratum in the *Conemaugh* formation of *Ohio*. It extends with some wants from *Columbiana County* on the north to *Lawrence County* on the south, but along its outcrop it shows much variation in character. The member may be represented by dark, carbonaceous shale; by this with nodules of dark to gray limestone; by dark gray limestone; by gray, calcareous shale;

¹Second Geol. Surv. *Pennsylvania*, Report Q, p. 34.

by gray to nearly black flint; by gray, shaly flint; and by various combinations of these. In general the most common representative is dark shale with nodular limestone in eastern Ohio and gray shale with gray to dark limestone or flint in the southern part of the State. With few exceptions in eastern Ohio the member consists of only one stratum of calcareous material but in central and southern Ohio it is normally made up of two beds of limestone or flint separated by from 10 to 30 feet of shale. This double structure is well recognized in Lawrence, Gallia, Vinton, Meigs, Athens, Perry, and Morgan counties. As indicated by the fauna, the Brush Creek member is largely of marine origin, commonly being very fossiliferous. In small areas, however, the strata appear to have been deposited in brackish water. The Brush Creek is the oldest marine limestone in the Conemaugh formation and represents a widespread invasion of the sea into the great coal formation basin lying between old Appalachia and the Cincinnati uplift. It was followed, however, by similar inundations that gave rise to the Cambridge, Portersville, Ames, and Skelley limestones. The Brush Creek member serves as a bench for reference in stratigraphic work as it is a fossiliferous stratum, as it is widely distributed, and as it is easily recognized along the outcrop. In a general way the deposits thicken in their extension southward across the State. The average measurement of the member is about 5 feet in eastern Ohio and at least 22 feet in the southern part of the field. Changes, but in a reverse order, are also evident in the intervals to other well-known members. The Brush Creek limestone is separated from the Cambridge limestone by an interval of 48 feet in eastern Ohio and by that of only 29 feet in southern Ohio. The contraction is somewhat similar with the beds lying between the Upper Freeport coal and the Brush Creek limestone, which in eastern Ohio measure on the average 96 feet and in southern Ohio 68 feet. The evidence when only Ohio is considered thus indicates that the invasion of the sea at this stage of Conemaugh time was from the south or southeast, for in that direction the member thickens gradually, becomes more calcareous in character, and contains a more diverse and better developed fauna. The source of the ferruginous sediments that make up the rocks lying above and below the Brush Creek member was apparently from the east or from old Appalachia. This view is supported by the general expansion of the intervals and by the increase in the coarseness of the sediments eastward across the State.

In the extension of the Brush Creek limestone across the State only the eastern part of Vinton County lies within the belt of outcrop. The main body passes to the east of this through Athens and Meigs counties. In the area under consideration such deposits are found along the ridges in eastern Brown, eastern Madison, Knox, eastern Vinton, and Wilkesville townships. Although the Brush Creek member

is the most definite stratigraphic unit in the Conemaugh formation of Vinton County, it is not a persistent deposit and undergoes some changes in character. It is wanting through lack of development and also through replacement by sandstone. This applies to both the lower and the upper benches of the member which normally are separated by about 27 feet of shale and sandstone. The lower stratum consists usually of dark, fossiliferous shale, of this with hard limestone, and of gray to dark flint; whereas the upper one is made up of gray, siliceous limestone or of gray to nearly black flint. From many measurements the average thickness of the lower bench is 11 inches and that of the upper layer is 2 feet. The materials on both of these horizons are very fossiliferous and the shales intervening in many places contain a few scattered remains. Conditions, especially locally, were not entirely marine throughout the stage of Brush Creek deposition, for in some areas sandstone, shale, and even coal in an impoverished form are present in the interval between the two regular benches of the member. The upper stratum of the Brush Creek limestone in southern Ohio appears to be the only part represented in the eastern portion of the State, the lower layer disappearing through lack of deposition long before it reaches that part of the field. The deposits of this limestone in Vinton County are not well enough exposed for a detailed study of its various relationships.

Brown Township.—In Brown Township only scattered deposits of Brush Creek limestone are present near the summits of the high ridges in the eastern part. The lower stratum is more frequently present than the upper one. On the high knob in the southeastern part of Section 18, the lower stratum is present at an elevation of 1,020 feet. It is a hard, blue, fossiliferous limestone about 9 inches thick. It is overlain by 35 feet of drab, siliceous shale and underlain by more than 2 feet of shaly Mason coal. The main stratigraphic features are well shown in the following composite record taken in the central part of Section 16:

	Ft.	In.
Shale, drab, siliceous	40	0
Shale with weathered limestone, fossiliferous, lower stratum of <i>Brush Creek</i> , altitude 1,015 feet.	1	0
Clay with thin coal bands.	2	6
Coal, very shaly, weathered.		0
Clay, dark, grainy	2	6
Shale, gray	14	0
Clay shale, pink	2	0
Shale, gray	2	0
Sandstone, shaly	1	0
Shale, gray	3	0
Clay shale, drab, pink, and mottled	8	0
Clay, gray, with limestone nodules, <i>Mahoning</i>	4	6
Shale and shaly sandstone, gray	24	2

	Ft.	In.
Sandstone, shaly.....	3	0
Shale, gray.....	2	4
Clay, impure, with ore nodules, horizon of <i>Upper Freeport</i> coal..	3	0
Shale and shaly sandstone, gray.....	10	0
Sandstone, massive, <i>Upper</i> and <i>Lower Freeport</i>	73	0
Coal blossom, <i>Middle Kittanning</i>	2	0

The Brush Creek limestone is also present near the top of the divide on the road that leads from Hope Furnace to King Hollow. South of Raccoon Creek exposures were observed 980 feet above tide on the high knob in the north central part of Section 13 and at about the same altitude in the western part of Section 7.

Madison Township.—The Brush Creek member in Madison Township is confined entirely to the high ridges in the eastern part. Where the upper stratum makes its appearance it is commonly a hard flint, dark gray to nearly black in color. Locally also the lower bench tends toward the flinty phase, but commonly it is either limestone or fossiliferous shale. In the northern part of the township the most western deposit observed is on the knob in the southeastern part of Section 30. The material is a ferruginous chert lying 1,060 feet above tide and about 50 feet above the Upper Freeport coal. At the forks of the road in the northeastern part of Section 24, the upper stratum is represented by approximately 2 feet of shaly limestone and black flint, the latter hard, brittle, and lustrous. Similar deposits were observed along the ridges in the northern and eastern parts of Section 18 where in a few places the bed thickens to 2 feet 6 inches and changes from the calcareous phase to nearly pure flint. The descent above tide is from 1,030 to 1,000 feet. The areas of such material are small in Section 17. The most conspicuous outcrop in Section 23 is near the school house, 1,080 feet above tide, in the northwestern part of the area. Some of the stratigraphic features are shown in the following record taken along the road in the central part of Section 16:

Conemaugh formation	Ft.	In.
Flint, light to gray, upper bench of <i>Brush Creek</i>	2	2
Shale and covered.....	16	6
Coal blossom.....		6
Shale and shaly sandstone.....	27	0
Limestone, shaly, very fossiliferous, lower bench of <i>Brush Creek</i>	1	2
Shale and covered.....	16	10
Coal and coaly shale, <i>Mason</i>	2	0
Clay and clay shale.....	5	4
Coal, <i>Mahoning</i>		6
Clay and shale.....	8	2
Shale and shaly sandstone.....	4	0
Ore, irregular.....		3

Allegheny formation	Ft.	In.
Coal smut, <i>Upper Freeport</i>		1
Clay, impure.....		11
Covered.....	10	9
Sandstone, shaly.....	4	0
Shale and covered.....	10	0
Sandstone, massive, soft, <i>Upper and Lower Freeport</i>	58	0
Shale and covered.....	6	0
Coal blossom, <i>Middle Kittanning</i>	1	0

The interval between the two Brush Creek limestones is here much above normal. The thin bed of coal intervening is probably correlative with the Brush Creek coal of Columbiana County and adjacent parts of eastern Ohio. Thin lenses of such material were also observed at this horizon elsewhere in Vinton County. It is not persistent, however, being absent more often than present. In the southeastern part of Madison Township the deposits of Brush Creek limestone are confined to the high ridges east of Flat Run. The elevation of the member is approximately 975 feet.

Knox Township.—All the main ridges in Knox Township have sufficient height to contain deposits of Brush Creek limestone. One or both beds, however, are frequently absent through lack of deposition or through replacement by sandstone. The altitude of the member is 990 feet in the west central part of Section 12, 850 feet in the southeast corner of Section 30, 968 feet in the southwestern part of Section 7, and 820 feet in the east central part of Section 25. The lower stratum is usually shaly or limy in character, whereas the upper one is commonly flinty.

In Section 12 the upper stratum is represented by 1 to 2 feet of flinty limestone which outcrops prominently along the main ridge. The deposits are more calcareous in the northeastern part of Section 6, in many places consisting of two layers of hard, blue limestone separated by a few inches of shale. The upper portion of the rock is locally brecciated. In sections 36 and 30 this stratum frequently gives way to sandstone and the lower one changes to a dark, fossiliferous shale. In the central part of the township the deposits have somewhat better development and continuity. The following record taken in the east central part of Section 27 is approximately representative:

	Ft.	In.
Shale, gray, parts covered.....	33	0
Shale, red.....	2	0
Coal blossom, <i>Wilgus</i>		6
Clay and covered.....	9	6
Sandstone, shaly.....	4	0
Clay shale, red, parts covered.....	15	0
Sandstone, massive.....	6	0

	Ft.	In.
Flint, light to gray... } Upper bench of <i>Brush Creek</i>	1	3
Flint, shaly, gray.... }	1	9
Shale, gray, soft.....	5	0
Covered.....	6	0
Shale, gray.....	16	0
Covered.....	3	0
Limestone, gray, fossiliferous, lower bench of <i>Brush Creek</i>	1	3
Coal and coaly shale, <i>Mason</i>	1	0
Shale and shaly sandstone.....	4	0
Sandstone, massive, <i>Mahoning</i>	60	0

The Brush Creek beds are also well developed south of this in sections 26 and 25, but are thin or absent in many places west of Racoon Creek in sections 1, 2, 7, and 8. The interval of separation of the two parts is from 20 to 35 feet. The lower stratum, especially if it is shaly in character, is far more fossiliferous than the upper one; but the species common to one are common to the other. The intervening shales also show some evidence of marine origin.

Vinton Township.—The deposits of Brush Creek limestone in Vinton Township are confined to the main ridges in the eastern part and to a few high knobs in the central part. Of the two the upper bench is by far the most persistent and the best developed; usually it is the only one present. Its thickness varies from 1 to 5 feet and its composition changes from an impure flint to dense, hard limestone. Along the ridges in sections 6 and 12 the Brush Creek member is represented by several thin layers of hard, blue limestone separated by shale partings. The thickness is from 2 feet to 4 feet 6 inches. On the knobs in the southern part of Section 23, and at an altitude of 880 feet, the horizon of the upper stratum is marked by flint varying from light gray to dark in color and from 1 to 3 feet in thickness. Small bodies of such material are also present in sections 22 and 20. The usual character of the material in the southeastern part of the township is shown in the following record taken in the northwest corner of Section 1:

	Ft.	In.
Clay shale, red, parts covered.....	10	0
Limestone, hard, blue, <i>Cambridge</i> , about in place.....	1	0
Clay shale and covered.....	9	0
Clay shale, red, with large nodules of fresh water limestone...	4	0
Shale, drab.....	3	0
Sandstone, shaly.....	25	0
Limestone, siliceous, blue, fossiliferous..	2	8
Sandstone, shaly, calcareous, with a few fossils, altitude 855 feet.....	5	0
Shale, siliceous, gray.....	7	0

Upper bench of *Brush Creek*

The member was observed with less development in parts of sections 2, 7, and 8. In places the material contains an abundance of well preserved fossils.

Wilkesville Township.—Although widely distributed in Wilkesville Township the Brush Creek limestone is poorly represented, except in local, isolated areas. It is usually impure limestone or calcareous shale. Through weathering the limestone is occasionally converted into a spongy iron ore in which the original fossils are still well preserved.

In Section 6, north, the member outcrops at an altitude of approximately 840 feet. The thickness of the bed is from 8 inches to 2 feet. The most prominent deposits in the northwestern part of the township are found in sections 30, 29, and 35. The position of the member with reference to some beds in the upper part of the Allegheny formation is given in the section below:

	Ft.	In.
Conemaugh formation		
Limestone, gray, fossiliferous, lower part siliceous, upper bench of <i>Brush Creek</i> , altitude 940 feet.....	1	4
Sandstone and covered.....	2	0
Shale and covered.....	28	4
Shales, parts covered.....	26	0
Clays, red to light.....	10	0
Clay shales, red to mottled.....	20	0
Shale, gray, part covered.....	18	6
Allegheny formation		
Coal blossom, <i>Upper Freeport</i>		6
Clay, impure.....	6	0
Shale and covered.....	20	0
Sandstone, massive, soft.....	14	0
Clay, shale, and covered, horizon of <i>Upper Freeport</i> coal...	8	0
Shale and shaly sandstone.....	53	0
Coal, shaly, <i>Middle Kittanning</i>		9
Clay, plastic, impure.....	1	6
Shales and covered.....	23	0
Coal blossom, <i>Strasburg</i>		6
Shale and covered.....	18	0
Coal blossom, <i>Lower Kittanning</i>	1	0
Clay, plastic.....	3	0
Sandstone and covered.....	24	0
Covered.....	5	0
Shale, black, fissile.....	2	0
Coal, weathered, <i>Clarion</i>	4	0
Clay, flint and plastic, good.....	6	0

At the forks of the road in the northeastern part of Section 35 the upper bench of the member consists of sandy limestone, 2 feet 8 inches thick, overlain by hard, blue limestone measuring 10 inches. Both are fossiliferous. The deposit outcrops 950 feet above tide.

The ferruginous or iron ore phase was observed along the ridge in the central part of Section 15. In the southern part of the township the Brush Creek member is not often present in characteristic form.

Economic value

The chief importance of the Brush Creek members and the associated shales in Vinton County is the contribution of a small quantity of calcareous matter to the soils derived from their decay. Such land is better fitted for raising grass, grains, fruit, and other products. The deposits are too thin and the stone too impure to be prepared economically either by crushing or by burning for agricultural purposes. Small quantities have been used in road building in a few places in Madison and Knox townships. Aside from foundations it has not been used as building stone.

BUFFALO SANDSTONE

Stratigraphy and extent

The Buffalo sandstone which is massively developed in Harrison, Tuscarawas, Carroll, and Guernsey counties is locally represented in the southern part of the State. The member appears to have been laid down as channel deposits which terminate abruptly when traversed at right angles to the line of flow of the old stream, which vary texturally from fine sand to coarse pebbles, and which have an irregular and confused stratification. The normal position of the Buffalo sandstone is between the Brush Creek and the Cambridge limestones, but where well developed it replaces one or both of these.

In Vinton County the Buffalo sandstone is not a conspicuous bed in the small areas in which it is due. The horizon is occasionally marked along the ridges in eastern Brown and eastern Madison townships, by bodies of a fine-grained, micaceous sandstone and in a few places in Knox Township by deposits of sandstone bearing thin lenses of conglomerate. The latter condition is shown in the following record taken in the northeastern part of Section 6, Knox Township:

	Ft.	In.
Covered.....	7	0
Conglomerate, very pebbly, pebbles fine to medium in size and com- posed of quartz.....	1	0
Sandstone, soft, micaceous.....		
Covered.....	7	0
Limestone, fossiliferous, part brec- ciated.....	5	0
Shale, calcareous, gray.....		7
Limestone, siliceous, blue, hard, fossiliferous.....		3
		8

The altitude of the outcrop is 960 feet. Locally in the eastern part of Vinton Township the Buffalo sandstone replaces the upper bench of the Brush Creek limestone. The Buffalo member is of little interest in Wilkesville Township except in a small area about 1 mile northwest of Wilkesville where it appears as a coarse, pebbly conglomerate the thickness of which is from 10 to 15 feet. It is best exposed in the north central part of Section 10 at an altitude of 900 feet. Its position is just above the Brush Creek limestone. The Buffalo sandstone is of no economic importance in Vinton County.

WILGUS COAL

The Wilgus coal, named by Condit in 1912 for deposits occurring near the village of Wilgus in Mason Township, Lawrence County, is best developed in the southern part of the State in Lawrence and Gallia counties. North of this small field the bed is thin, impure, and uncertain. Its position is directly or only a few feet at most below the Cambridge limestone. In Vinton County the Wilgus horizon is marked by a thin layer of shaly coal at a few places in the eastern part of Knox and Wilkesville townships.

CAMBRIDGE LIMESTONE

The Cambridge is the second marine limestone in ascending order in the Conemaugh formation of Ohio. It outcrops with many wants and much variation in character from Columbiana County on the north to Lawrence and Gallia counties on the south. In southern Ohio its position is 20 to 30 feet above the Brush Creek limestone and 110 to 130 feet above the Upper Freeport coal. In Vinton County the member is confined to a few high knobs in the eastern part of Knox and Wilkesville townships. The thickness of the stratum is usually less than 10 inches. The Cambridge is the youngest definite Conemaugh member exposed in Vinton County.

CHAPTER IV

OIL AND GAS

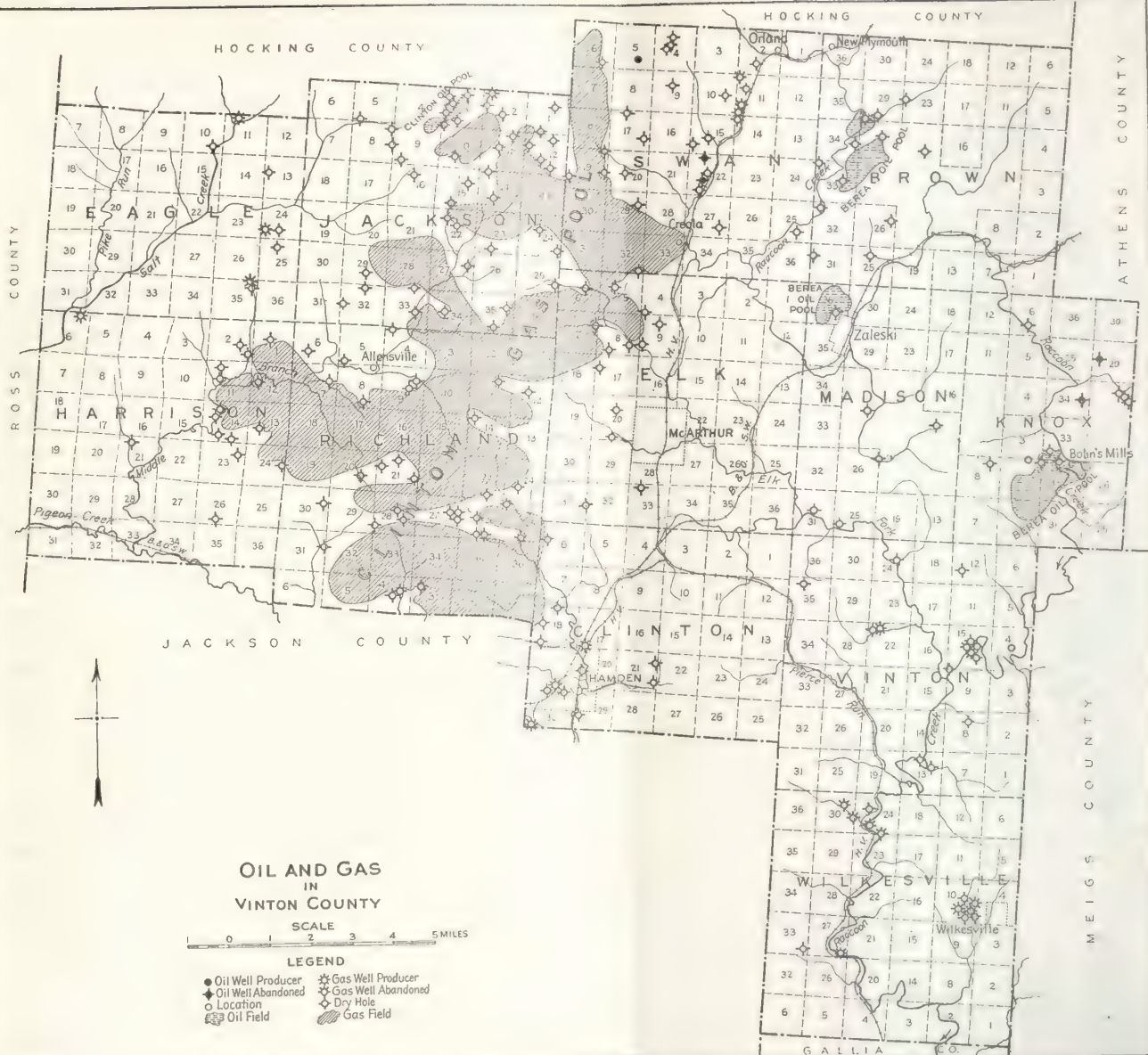
The search for oil and gas in Vinton County appears to have begun as early as 1865 when a test of the rocks was made on Raccoon Creek near the center of Section 6, Knox Township. Neither oil nor gas was obtained. Near-by territory, however, was tested by the drill in 1862 when a well was sunk on the William Poland property just south of the county line and about one-half mile southwest of Richland Furnace. It yielded a small volume of gas which was not utilized but flowed for many years without exhaustion. In 1867 on land of John Calvin, located on Raccoon Creek in the central part of Section 10, Vinton Township, the drill at a depth of 490 feet released a reservoir of gas which flowed in the atmosphere with much vigor for nearly ten years before an attempt was made to utilize the fuel in the production of lampblack. By this time the well was much depleted and soon failed entirely. The gas was found in the Big Injun sand which is correlative with the Black Hand conglomerate so highly developed to the northwest in Hocking County. Between 1867 and 1897 only a few scattered wells were drilled in Vinton County, and these were failures, but they revealed the presence of sandstone deeply buried and favorable for oil and gas accumulation. The production of natural gas in such quantities as to be marketable began in 1898 when a test of the "Clinton" sand on the William Poland property in Section 28, Richland Township, gave a strong flow with high rock pressure. This soon led to the development of large fields in the "Clinton" sand in Richland, Harrison, Eagle, Jackson, Swan, and Elk townships and of a small reservoir in the Hamden sand in Richland and Clinton townships. These are steady producers and are not exhausted. A small pool of oil was struck, in 1899, in the "Clinton" sand on the headwaters of the East Fork of Queer Creek in northern Jackson Township and another about 1900, in the Berea sand near Bolins Mills in central Knox Township. Since then the Berea has yielded some oil and gas just north of Zaleski in Madison Township and along Raccoon Creek in the west central part of Brown Township. The total number of wells drilled in Vinton County is nearly 700 of which 70 per cent have produced oil or gas in paying quantities. The chief production is gas from the "Clinton" sand and oil from the Berea.

General consideration of the deep-seated rocks

Some of the deep-seated rocks in Vinton County are known in Ohio only through the meager evidence afforded by the drill as they do not appear at the surface within the State nor do they outcrop near its confines. They are known, therefore, only in a general way. In Vinton County the steel bit has descended to a depth of 4,295 feet and reached what is apparently the St. Peters sandstone, below the base of the Trenton limestone. The rocks so penetrated and those exposed at the surface thus range from the St. Peters sandstone of Lower Ordovician time to the Cambridge limestone of middle Conemaugh age. The total thickness of the rock section is approximately 5,000 feet. In the Ordovician, Silurian, and Devonian systems the rocks are mainly dolomites, limestones, and shales; in the Mississippian they change to shales, sandstones, and conglomerates; and in the Pennsylvanian they consist principally of shales, sandstones, and conglomerates with thin beds of limestone, coal, clay, and iron ore. Of these the sandstones are the ones most sought by the driller as they form the natural reservoirs for the storage of the valuable hydrocarbons, oil and gas. In this kind of strata the essential feature is porosity which not only allows storage in the capillary spaces but circulation through them. The character of the overlying beds should also be considered. Such rock must be sufficiently impervious to prevent the escape of the oil and gas. Geological structure of some type such as anticlines, domes, or enclosed lenses is necessary in order to entrap the oil and gas and so to prevent them from traveling up the slope of the sandstones to the surface and escaping through slow dissipation. The oil geologist must also consider other factors such as gravity, viscosity, temperature, diffusion, pressure, and solubility. The oil and gas bearing rocks of most importance in Vinton County will be considered briefly.

General features of drillers' record in Vinton County

Description	Thickness in feet			Probable geological equivalents
	Average	Minimum	Maximum	
Limestone, hard, fossiliferous....	1	0	2	Cambridge limestone
Shales, red to gray, soft.....	13	10	20	
Sand, Buell Run.....	15	0	40	Buffalo sandstone
Shales and clays.....	128	100	150	



General features of drillers' record in Vinton County—Continued

Description	Thickness in feet			Probable geological equivalents
	Average	Minimum	Maximum	
Sand, Pecker or 300-foot.....	18	0	60	Upper Freeport sandstone
Shales, coals, and clays.....	146	120	170	
Sand, Macksburg or 500-foot....	10	0	40	Possibly Clarion sandstone
Shales, clays, coals.....	136	110	150	
Sand, Salt.....	65	10	90	Massillon sandstone
Coal, Jackson, No. 1.....	2	1	3	Quakertown or No. 2 coal
Shales, clays, and coals.....	53	40	75	
Sand, Maxton, very patchy.....	5	0	50	Sharon conglomerate
Limestone, seldom present.....	0	0	40	Maxville limestone
Sand, Keener, with shales.....	132	100	175	Possibly represented by the Vinton and Allensville members
Sand, Big Injun with Squaw at base.....	125	50	300	Black Hand sandstone in some areas and Byer sandstone in others
Shale, blue, gritty.....	377	200	500	Cuyahoga shale
Sand, gray to brown, Hamden...	15	5	30	Cuyahoga sandstone
Shale and shaly sandstone.....	60	40	80	Cuyahoga shale
Shale, black, Little Cinnamon...	21	10	35	Sunbury shale
Sand, Berea Grit.....	34	8	60	Berea sandstone
Shale, gray to pink.....	80	65	100	Bedford shale
Shale, brown to black, Big Cinnamon.....	792	630	1,070	Ohio shale
Shale, gray, local.....	10	0	25	Olentangy shale

General features of drillers' record in Vinton County—Concluded

Description	Thickness in feet			Probable geological equivalents
	Average	Minimum	Maximum	
Limestone, Big Lime.....	670	590	960	Silurian and Devonian limestones and dolomites from the Bisher to the Delaware members. The "First water" in the Big lime is on the general horizon of the Sylvania sandstone or "Austinburg Gas" sand and the "Second or Big water" on that of the Hillsboro sandstone or "Newburg Gas" sand
Shale, gray, green, brown, and pink.....	154	120	220	Rochester shale of New York and Alger shale of Ohio
Limestone, first shell....	6	0	10	Irondequoit limestone of New York and Dayton limestone of Ohio Wolcott limestone of New York and Brassfield limestone of Ohio
Shale, gray, limy.....	16	5	40	
Limestone, second shell..	7	5	15	
				Little Lime
Shale, gray to pink, soft, Pencil cave.....	17	5	45	Sodus shale of New York
Sand, Clinton.....	17	0	50	Whirlpool sandstone of New York
Shale, blue, white, and red, Red Medina.....	190	.....	.....	Queenstown shale of New York and possibly Upper Richmond of Ohio
Shales and thin limestones, dark..	1,028	.....	.....	Richmond, Maysville, and Cynthiana beds
Limestone, shaly, dark, Trenton.	632	.....	.....	Trenton limestone
Sand, St. Peters.....	35	.....	.....	St. Peters sandstone

ST. PETERS SANDSTONE

The St. Peters sandstone, named for exposures on the St. Peters (now Minnesota) River of Minnesota, is locally present over a wide

area in the Upper Mississippi Valley and north of Lake Superior in Canada. It is characterized by marked irregularity in thickness and by roundness and purity of the sand grains. In Ohio the Lower Ordovician rocks with the included St. Peters are so deeply buried that they are reached only by the drill in the western and the central parts of the State. The evidence thus secured is far from conclusive but it indicates that sandstone at the St. Peters horizon is locally present across the area. In some wells the bed is not definitely revealed, whereas in others it is prominent, the thickness varying from 10 to 150 feet or more. This horizon is usually indicated by a heavy flow of blue-lick water. In Ohio the position of the St. Peters sandstone is approximately 2,100 feet below the base of the Big lime and 1,950 feet below the top of the "Clinton" sand. It lies just below the "Trenton" limestone of the driller which is geologically equivalent to the Stones River, Black River, and Trenton formations and which has a mean thickness of 650 feet. The St. Peters is of little importance as a source of oil or gas.

In Vinton County the St. Peters horizon has been reached (1925) in only one test, the A. J. Garrett well in Section 32, Jackson Township. It was drilled by the Ohio Fuel Gas Company in June, 1920. The record kindly furnished by this company is as follows:

Kind of rock	Thick- ness	Top	Bottom	Remarks
Not recorded.....	743	0	743	Waverly shales and sandstone. Sunbury shale
Sand <i>Berea Grit</i>	36	743	779	Berea sandstone
Not recorded.....	801	779	1,580	Bedford and Ohio shales
Limestone, <i>Big lime</i>	643	1,580	2,223	Devonian and Silurian limestones from the Delaware to the Bisher
Not recorded.....	144	2,223	2,367	Rochester shale in part
Limestone, <i>First shell</i>	4	2,367	2,371	Dayton limestone?
Not recorded.....	14	2,371	2,385	Calcareous shales
Limestone, <i>Second shell</i>	3	2,385	2,388	Brassfield limestone?
Not recorded.....	17	2,388	2,405	Sodus shale?
Sand, <i>Clinton</i>	6	2,405	2,411	Whirlpool sandstone
Not recorded.....	37	2,411	2,448	Largely shale
Shales, red to light, <i>Medina</i> ..	152	2,448	2,600	Queenstown shale in part
Shales, dark, limy.....	1,028	2,600	3,628	Richmond, Maysville, and Eden groups
Limestone and shale, dark, <i>Trenton</i>	632	3,628	4,260	Stones River, Black River, and Trenton limestones
Sand and not recorded.....	35	4,260	4,295	St. Peters sandstone in part
Total depth.....			4,295	

The position and character of the St. Peters sandstone, shown in the above record, are verified by many tests extending across the central part of the State from Adams County on the Ohio River to Lorain County on Lake Erie and by others farther to the west on the Cincinnati uplift. Throughout the entire area the sand has proved to be unproductive save for occasional small flows and showing of oil or gas. In most of the wells the drill on entering the bed released a strong flow of brine heavily charged with hydrogen sulphide. In a light colored, granular dolomite, lying near the horizon of the St. Peters sandstone, a small pool of oil has been struck near Newark, Licking County. The position of the "pay" is about 670 feet below the top of the Trenton formation and about 2,020 feet below that of the "Clinton" sand. The overlying Trenton rocks consist largely of light gray to dark limestones and dolomites which are massive in character and drill slowly. They are interbedded, however, with some shale usually recorded as "breaks." The drillings of the harder parts are flaky in character and contain evidence of an abundant fauna. The rocks of the Cincinnati group, lying above the Trenton, are largely shales in which many thin limestones are interbedded at various horizons. The material is very fossiliferous. The formations represented are the Eden, Maysville, and Richmond.

"CLINTON" SAND

In Ohio the "Clinton" sand ranks first in the production of natural gas and next to the Trenton in that of oil. The producing field extends in a discontinuous way from Jackson County on the south to Cuyahoga County on Lake Erie. Its length is nearly 200 miles and its width from 1 to 40 miles. Along this extension pools either large or small are present in 18 counties. To the east of the main field, under deep cover, the sand is present in good thickness but is not productive, whereas to the west it is much impoverished and even wanting. The "Clinton" sand is of Medina age. It appears to be correlative with the Whirlpool sandstone so well exposed in the gorge below Niagara Falls. The underlying red Medina shale of the driller is the Queens-town shale and the soft, overlying layer known as the Pencil cave has the position of the Sodus shale of the New York section. The Little lime of the driller is represented apparently by the Irondequoit and Wolcott limestones of New York and by the Dayton and Brassfield limestones of southwestern Ohio.

The "Clinton" sand is fine to coarse in texture and usually light in color; although in places the deposits contain lenses varying from light gray to pale red. Frequently the stratum is more or less broken by shale partings known to the driller as breaks. The sand may be open or compact, depending on the fineness of grain and the quantity of bonding components.

In Vinton County the "Clinton" sand is the great reservoir from which large volumes of natural gas have been drawn since 1898. Some oil has been produced also in a few small areas. In the county the drill has gone to or below this horizon in approximately 470 tests of which nearly 70 per cent have been productive. The field as now outlined (1925) includes most of Richland, eastern Harrison, eastern Eagle, most of Jackson, western and central Swan, and northwestern Elk townships. Scattered tests yielding only a showing of oil or gas have also been drilled in Brown, Madison, Clinton, Vinton, and Wilkesville townships. As elsewhere the "Clinton" sand is unsteady in thickness and variable in character. Locally it is absent or at least so poorly developed that the driller fails to detect the stratum. The usual thickness of the bed is between 10 and 25 feet. The sand is very free from brine except in the southeastern part of Vinton County where much water was encountered in nearly all the tests thus far made. The accumulation of oil and gas in the member is dependent not so much on rock structure as on the lenticular character of the sand layers. In this county the position of the "Clinton" sand is on the average about 45 feet below the top of the Little lime and nearly 200 feet below the base of the Big lime. These intervals, however, are subject to much variation, through local causes and through a general expansion of the rocks to the southward.

The "Clinton" sand in Vinton County descends rapidly to the east and slightly to the south. This is caused by the regular dip of the rocks to south of east, augmented by the expansion especially of the Devonian shales and of the great mass of the Devonian and Silurian limestones. The normal dip of the surface rocks is 28 feet per mile to the east and 12 feet per mile to the south. Across the northern part of the county from the Ovitt No. 1 well in Section 11, Eagle Township, to the Hewett well in Section 34, Waterloo Township, Athens County, the Berea-"Clinton" interval thickens at a rate of 41.28 feet per mile. The expansion of the strata from the top of the Berea sand to the top of the Big lime is 28.83 feet per mile, that of the Big lime is 10.23 feet, and that of the beds between the Big lime and the "Clinton" sand is 2.22 feet. With equal elevation and for every mile east the "Clinton" sand therefore lies nearly 69 feet deeper. Similarly measured from the B. E. Epstein well in Section 32, Richland Township, to the Cline well in Section 12, Vinton Township, the eastward thickening of the Berea-"Clinton" interval is 36.42 feet. The total eastward dip of the "Clinton" sand is therefore more than 64 feet per mile.

The average expansion of the Berea-"Clinton" interval to the southward is only 5.48 feet per mile as measured along two lines across the county. One of these is from the Susan Shaw well in Section 17, Benton Township, Hocking County, to the Charles Dickerson No. 1 well in Section 34, Coal Township, Jackson County; and the other from

the Columbus Brick and Terra Cotta Company well in Section 23, Starr Township, Hocking County, to the J. E. Newsom well near Wilkesville, in Vinton County. The expansion of 5.48 feet, plus normal dip of 12 feet, thus causes the Clinton sand to descend more than 17 feet to the mile to the southward. Such features, that is both the dip and the expansion, should be duly considered by those drilling in unprospected areas to the east and south. The position of the "Clinton" sand below the base of the Big lime should also be taken into account, as this increases nearly 2 feet to the mile eastward and about 3 feet to the mile southward. The "Clinton" sand lies about 140 feet below the base of the Big lime in the northwest part of the county, 210 feet in the northeast part, 180 feet in the southwest part, and 250 feet in the southeast part.

The main guides of reference for the driller are the Berea sand with the black Sunbury shale above it; the Big lime lying below the great mass of Ohio shale, known as the Big Cinnamon; and the Little lime or shells found in the shales below the Big lime. The position of the "Clinton" sand is not far below the Little lime or far above the red shales known to the driller as the red Medina. When the red Medina or Queenstown shale is reached the horizon of the "Clinton" sand has been passed.

Brown Township.—In the western half of Brown Township five wells have been drilled to the "Clinton" sand without successful results. Along Twomile Run in the western part of Section 23, the Pure Oil Company in 1922 drilled a test on the property of G. P. Drayer. The altitude of the well head was 760 feet and its geological position near the level of the Lower Mercer limestone. The drill reached the Berea sand at a depth of 904 feet and the "Clinton" at that of 3,043 feet. The Berea sand was 43 feet thick, and yielded about 1 barrel of oil. The "Clinton" sand, although 17 feet thick, was totally dry. Near the mouth of Twomile Run also on the G. P. Drayer property, another well was drilled by the Pure Oil Company in 1922. The results were about $1\frac{1}{2}$ barrels of oil in the Berea sand and 200,000 cubic feet of gas per day in the "Clinton." In 1914 a deep well was drilled on a western fork of Hope Hollow on land of G. P. Drayer. The location is one and one-half miles northwest of Hope Furnace and its position near the level of the Clarion coal and 840 feet above tide. The Berea sand was found at a depth of 1,024 feet, had a thickness of 46 feet, and gave a test of about 1 barrel of oil. The "Clinton" sand measured 34 feet and gave an initial flow of 500,000 cubic feet of gas per day. The drill reached a depth of 3,180 feet before work was suspended. The Preston Oil Company in September, 1914, completed a "Clinton" well on the H. E. Pence property located in the southwestern part of Section 28. The record is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Loam.....	80	0	80
Coal (<i>Quakertown</i>)?.....	3	80	83
Shale.....	237	83	320
Sand, <i>Big Injun</i>	55	320	375
Shales.....	505	375	880
Sand, <i>Berea</i>	50	880	930
Shales, <i>Bedford and Ohio</i>	1,070	930	2,000
Limestone, <i>Big lime</i>	754	2,000	2,754
Big water at 2,563 feet.			
Shales.....	186	2,754	2,940
Limestone and shale, <i>Big shell</i>	10	2,940	2,950
Shales.....	10	2,950	2,960
Sand, white.....	5	2,960	2,965
Sand, red.....	3	2,965	2,968
Sand, white.....	6	2,968	2,974
Shales.....	24	2,974	2,998
Total depth.....			2,998

The "Clinton" sand made a good showing of oil and the Berea sand sufficient for a producing well which is still pumping one-half barrel per day. On the E. W. Strong property in the northwest part of Section 31, the Preston Oil Company in January, 1915, also made a test of both the Berea and "Clinton" sands which were reached at depths of 967 and 3,019 feet respectively. About 2 barrels of oil was bailed from the upper bed and 10 gallons from the lower one.

Swan Township.—The western part of Swan Township is included in the great "Clinton" gas field that extends across Vinton County from north to south. In small areas oil has also been found in paying quantities. In this township drilling began about 1901 and since then 95 deep tests have been made of which 67 gave good yields of either gas or oil. The main gas field lies in the western part of the township in sections 6, 7, 18, 19, 30, and 31, and in the southern part in sections 28, 29, 32, and 33. Two small oil pools are found, one near Hue in sections 5, 6, and 7, and another south of this in a ravine in the northeast part of Section 30 and the southeast part of Section 19. The following record of a well drilled in February, 1920, by the Ohio Fuel Gas Company on the Caroline Williams property in the southwestern part of Section 29 is about representative:

	Thickness Ft.	Top Ft.	Bottom Ft.
Sand, <i>Berea</i>	43	745	788
Shale, <i>Bedford, Ohio, and Olentangy</i>	950	788	1,738
Limestone, <i>Big lime</i>	707	1,738	2,445
Shales.....	149	2,445	2,594
Limestone, shaly, <i>First shell</i>	10	2,594	2,604
Shale.....	17	2,604	2,621

	Thickness Ft.	Top Ft.	Bottom Ft.
Limestone, shaly, <i>Second shell</i>	6	2,621	2,627
Shales.....	12	2,627	2,639
Sand, " <i>Clinton</i> "	19	2,639	2,658
Total depth.....			2,666

The altitude of the well head is 793 feet and its position near that of the Quakertown coal. The daily production was 1,488,000 cubic feet of gas with a rock pressure of 810 pounds.

In the eastern and north central parts of Swan Township the drill has penetrated the "Clinton" sand in a number of places without satisfactory results. No pool has been developed but good "showings" are not uncommon. The sand is present with fair thickness and continuity but appears to be too fine and hard to allow accumulation. In the producing field in Swan Township many of the gas wells were large, having an initial flow of 1,000,000 to more than 5,000,000 cubic feet per day. The rock pressure varied considerably but in general it was between 700 and 900 pounds. In the few oil wells near Hue the initial production was from 5 to 50 barrels of dark greenish oil of medium gravity. The decrease was rapid but a small yield has been maintained for many years. Swan Township is very thoroughly prospected except small areas east of the Hocking Valley Railway.

Jackson Township.—The search for oil and gas in Jackson Township began in the summer of 1899 on the headwaters of the East Fork of Queer Creek in sections 3 and 4. Testing soon led to the development of a small oil pool and to the opening of a large gas field which eventually included sections 2, 9, 10, 11, 12, 13, 14, 22, 23, 24, 28, 29, 34, 35, and 36. In this township the "Clinton" sand has been reached by the drill in every section except 6, 7, 17, 18, 19, 20, 21, 26, 30, and 31. The total number of wells drilled is nearly 100 of which about two-thirds have produced gas or oil in commercial quantities. The history of the early development is recorded by Bownocker as follows:¹

"In the Jackson Township pool the first well was completed in August, 1899. By September, 1902, five oil wells, one gas well, and three dry holes had been drilled. Nearly all of these lie in sections 3 and 4, along the Vinton-Hocking line. These wells are now (1910) the property of the Southern Ohio Oil Company. Two new wells were drilled near these in 1909 and small producers secured. These belong to the Locust Grove Ridge Oil and Gas Company. Early wells ranged in production from 10 to 70 barrels per day, later ones being smaller. In the spring of 1902 the four producing wells then completed were yielding 125 barrels a day. By the following September the production from five wells had dropped to 109 barrels and in July, 1910, to 12 barrels or less, one well alone producing nearly one-half of this. At the same time the two wells drilled in 1909 were making 7 barrels per day. The gas pressure is strong with the

¹ Geol. Surv. Ohio, Fourth Series, Bull. 12, p. 42.

result that an occasional flow of oil still (1910) takes place. The oil has a density of $47\frac{1}{2}^{\circ}$ Baume and a green color, but when viewed in small quantity with transmitted light, its color is amber. The producing sand is spotted, and this increases the hazard of drilling, but it is soft, and consequently the wells seldom require shooting. Commonly the 'pay' has the color of brown sugar, but sometimes it changes to red-brown."

At present (1925) this small pool contains seven active wells with a total production of about 12 barrels per day.

The development of the gas field in Jackson Township is mainly the work of the Ohio Fuel Gas Company. Many of the wells were large, having an initial flow of 2,000,000 to 10,000,000 cubic feet per day. The record of the J. Seitz No. 1 well in Section 26 is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	20	0	20
Sand, yellow.....	35	20	55
Shale and shells.....	90	55	145
Sand.....	70	145	215
Shale.....	55	215	270
Sand.....	60	270	330
Shells and shale.....	270	330	600
Sand.....	100	600	700
Shale and shells.....	85	700	785
Sand, <i>Buena Vista</i>	55	785	840
Shale.....	5	840	845
Shale, black, <i>Sunbury</i>	25	845	870
Sand, <i>Berea</i>	40	870	910
Shale, light.....	12	910	922
Shale, red.....	103	922	1,025
Shale, black.....	40	1,025	1,065
Shale, light to dark...	195	1,065	1,260
Shale, dark.....	110	1,260	1,370
Shale, light.....	140	1,370	1,510
Shale, dark.....	150	1,510	1,660
Shale, light.....	138	1,660	1,798
Limestone, Big lime, <i>Devonian and Silurian</i> ...	678	1,798	2,476
Shale, red.....	124	2,476	2,600
Shale, green.....	25	2,600	2,625
Limestone, First shell, <i>Dayton?</i>	10	2,625	2,635
Rock, red.....	12	2,635	2,647
Limestone, Second shell	6	2,647	2,653
Shale, red and white, <i>Sodus?</i>	13	2,653	2,666
Sand, " <i>Clinton</i> ," Whirlpool.....	17	2,666	2,683
Total depth.....			2,730

Water at 170, 280, 2,148, and 2,288 feet. A little gas at 625 feet.

In the above log a number of the beds as defined by the driller are distinctly recognized on the outcrop at distant localities. The

black shale, 25 feet thick and 845 feet below the surface, is the Sunbury which is exposed at many places along the Scioto River near Chillicothe. The underlying Berea sandstone is also well represented along the outcrop over a wide area to the west. The succession of red shale below the Berea is more typical of central than southern Ohio. It is representative Bedford shale which has a wide range in central and northern Ohio. In the succession of black and light colored shales, from 1,065 feet to 1,798, the dark portions with the light interbedded layers are Ohio, and the light, basal portion is apparently the Olentangy. The shale, variously colored and lying below the Big lime, is similar in many respects to the Rochester shale exposed in the gorge at Niagara Falls. The shells and red rock, from 2,625 to 2,653 feet, is not greatly different from the Dayton and Brassfield limestones of southwest Ohio and from the Irondequoit and Wolcott limestones of the New York section. The "Clinton" sand of the driller is one of the Medina beds of New York, apparently the Whirlpool member.

Eagle Township.—In its extension westward from Jackson into Eagle Township the "Clinton" sand becomes so thin and patchy that few paying wells have been found. One producer was secured in the northwest part of Section 11; one in the southwest part of Section 24; and another in the northeast corner of Section 35. The best of these is on the Thomas S. Slagle farm in Section 24, and had an initial yield of 2,500,000 cubic feet of gas per day. The Berea sand was reached at a depth of 662 feet and the "Clinton" at 2,244. One or more tests showing little or no gas have also been drilled in sections 10, 13, and 25.

Harrison Township.—Harrison Township has been a profitable field for the driller as the "Clinton" sand in the northeast part has yielded large quantities of gas for many years. The producers are located as follows: six in Section 1, six in Section 12, four in Section 11, four in Section 14, two in Section 13, and two in Section 24. A small gas well was also obtained in the northeast part of Section 6. The drill failed to release satisfactory flows of gas in one or more trials in sections 2, 21, 23, and 26. A few of the wells also show some oil of the usual "Clinton" grade, but no pool has been developed. In the eastern part of the township the Berea sand lies about 450 feet and the "Clinton" nearly 2,000 feet below the valley floors.

Richland Township.—Richland Township has been a fruitful area for the driller since 1898 as the "Clinton" sand in most of the area has been highly productive of natural gas. For a comparatively shallow bed, the Hamden sand, in a small pool in the southeast part of the area has also been a good contributor. In all about 225 wells have been drilled in this township. Of these nearly 190 went to the "Clinton" sand and the remainder only to the Hamden or to the Berea. Of the total, only 35 wells were dry or were too small to be worth tubing.

The chief production in the "Clinton" is in sections 1 to 4, 7 to 23, 25 to 29, 32 to 36, 3 south, 4 south, and 5 south. That in the Hamden is confined largely to sections 35, 36, 1 south, 2 south, and 3 south. Tests without satisfactory results were made only in sections 5, 6, 24, 30, and 31. In a large percentage of the "Clinton" wells the initial flow was from 1,000,000 to 10,000,000 cubic feet per day, and the rock pressure from 720 to 900 pounds. One of the largest gas wells ever drilled in the State was that completed in September, 1917, by the Ohio Fuel Gas Company on the farm of Ella Gibson, in the north central part of Section 19. The log of this well given below was supplied by the Ohio Fuel Gas Company:

	Thickness Ft.	Top Ft.	Bottom Ft.
Not recorded, <i>Waverly</i> shales and sandstones. . .	584	0	584
Sand, <i>Berea</i>	24	584	608
Not recorded, <i>Bedford</i> , <i>Ohio</i> , and <i>Olentangy</i> shales.....	807	608	1,415
Limestone, <i>Big lime</i>	583	1,415	1,998
Not recorded, <i>Rochester</i> shale.....	113	1,998	2,111
Limestone, First shell. } <i>Dayton and Brassfield</i>	2	2,111	2,113
Not recorded..... } limestones	56	2,113	2,169
Limestone, Second shell }	6	2,169	2,175
Not recorded.....	6	2,175	2,181
Sand, " <i>Clinton</i> ," <i>Whirlpool</i>	9	2,181	2,190
Total depth.....			2,190

In this test the drill started near the contact between the Mississippian and Pennsylvanian formations at an altitude of 878 feet. The flow of gas was so large that it could not be gauged accurately but it was estimated at 20,000,000 cubic feet per day. The rock pressure was 850 pounds.

The field is very irregular in outline and is divided by breaks or dry areas in which the sand is generally present but thin and hard. One of these passes across the field in sections 24, 26, 27, 28, and 29. Unproductive, tongue-like areas also extend into the reservoirs both from the east and the west. The cause of these features is not known but it appears to be due to the lenticular character of the sand and also to the low porosity through filling of the cavities of the stone with cements.

Elk Township.—The "Clinton" sand in the northwest part of Elk Township has proved highly productive of natural gas; but elsewhere, although tested by the drill in a number of places, it has failed to give more than a showing of gas and little evidence of oil. In all the sand has been tested in 42 places, and of this number 30 gave gas in paying quantities and 12 were dry. The producers are distributed

as follows: 5 in the southern half of Section 5; 5 in the southern part of Section 6; 16 well distributed over Section 7; 3 in the northeast part of Section 8; and 1 in the north central part of Section 18. One or more dry holes are located in sections 4 to 9, 17, 20, and 33. To the present (1925) work has been confined entirely to the western half of the township, and nearly all of the wells were drilled by the Ohio Fuel Gas Company since 1916. The log of the John Howell No. 1 well in the northwest part of Section 7 and drilled by the above firm in January, 1919, is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Not recorded.....	875	0	875
Sand, <i>Berea</i>	40	875	915
Not recorded, <i>Bedford, Ohio</i> , and <i>Olentangy</i> shale	913	915	1,828
Limestone, <i>Big lime</i>	677	1,828	2,505
Not recorded, <i>Rochester</i> shale.....	153	2,505	2,658
Limestone, First shell.....	5	2,658	2,663
Not recorded.....	16	2,663	2,679
Limestone, Second shell.....	5	2,679	2,684
Not recorded.....	11	2,684	2,695
Sand, " <i>Clinton</i> ," <i>Whirlpool</i>	30	2,695	2,725
Total depth.....			2,729

The initial flow of this well was 4,257,000 cubic feet of gas per day and the rock pressure 600 pounds. The usual flow, however, of most of the wells in this part of the field was between 500,000 and 3,000,000 cubic feet. The variation in the rock pressure in different wells was from about 400 to 900 pounds.

Madison Township.—The "Clinton" sand in Madison Township has been tested in only a few places and results thus far have not been encouraging. The Preston Oil Company in 1915 completed a test on the E. W. Strong property just north of Zaleski in Section 36, the altitude of the well head being 760 feet. The record furnished by the Preston Oil Company is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	85	0	85
Coal, <i>Bear Run</i>	5	85	90
Shale.....	2	90	92
Coal, <i>Quakertown</i>	2	92	94
Shale.....	226	94	320
Sand, <i>Big Injun</i>	380	320	700
Shale.....	145	700	845
Shells, <i>Cuyahoga</i> in part.....	3	845	848
Shale.....	43	848	891
Sand, <i>Berea</i>	41	891	932
Shales and sands, <i>Bedford, Ohio</i> , and <i>Olentangy</i>	1,106	932	2,038
Limestone, <i>Big lime</i> . Water at 2,663 ft.....	750	2,038	2,788

	Thickness Ft.	Top Ft.	Bottom Ft.
Shales, <i>Rochester</i>	174	2,788	2,962
Limestone shells.....	8	2,962	2,970
Shale.....	23	2,970	2,993
Sand?.....			
Shale.....	37	2,998	3,035
Sand, red " <i>Clinton</i> "...	7	3,035	3,042
Shale.....	5	3,042	3,047
Sand, " <i>Medina</i> ".....	5	3,047	3,052
Not recorded.....	45	3,052	3,097
Total depth.....			3,097

In this well the "Clinton" sand was dry and the Berea sand made only a showing of gas. On a tributary of Wheelabout Creek, nearly 2 miles east of south of Zaleski, citizens drilled a well on the E. Fischer property in 1919. The plan was to drill to the "Clinton" sand but work is reported to have stopped at 3,000 feet, just short of that horizon on account of caving. Near Vinton Furnace two "Clinton" tests were drilled by the Vinton Furnace Company in 1913. The one located near the central part of Section 31 went to a depth of 3,047 feet. The Berea sand was charged with brine and the "Clinton", although about 20 feet thick, was devoid of oil or gas in paying quantity. The other well was drilled at the mouth of a small north tributary of Elk Fork in the southwest part of Section 25, and to a depth of 3,037 feet. The "Clinton" sand, about 30 feet in thickness and broken in character, was dry but the Berea sand, at a depth of 960 feet, made a showing of both oil and gas.

Vinton Township.—Testing of the shallow sands in Vinton Township began as early as 1865 but that of the deeper "Clinton" was not started until 1909, and since then the bit has reached the lower horizon in six wells. The first of these was drilled on the V. E. Cotterill farm, near Racoon Creek in the northeastern part of Section 13. The well head was 645 feet above tide. The bit reached the Maxton sand, about 40 feet in thickness and with a showing of oil, at a depth of about 300 feet; the Berea sand, hard and dry, at approximately 900 feet; the Big lime, 900 feet thick, at 2,160 feet; and the "Clinton" sand, thin and limy, at 3,210 feet. The tools stopped in shale at a depth of 3,268 feet. On the A. Radcliff farm, now owned by G. R. Morris, located on the small stream in the north central part of Section 8, the Ohio Fuel Gas Company drilled a "Clinton" well in 1919 with only a showing of oil and gas. The elevation of the well head was 710 feet. The log is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Not recorded.....	510	0	510
Sand, <i>Big Injun</i>	125	510	635

	Thickness Ft.	Top Ft.	Bottom Ft.
Not recorded.....	483	635	1,118
Sand, <i>Berea</i>	30	1,118	1,148
Not recorded, <i>Bedford, Ohio, and Olentangy</i> shales.....	1,152	1,148	2,300
Limestone, <i>Big lime</i> . Water at 2,365 ft	778	2,300	3,078
Not recorded, <i>Rochester</i> shale.....	155	3,078	3,233
Limestone, First shell. }	9	3,233	3,242
Not recorded..... } <i>Dayton and Brassfield</i>	39	3,242	3,281
Limestone, Second shell }	15	3,281	3,296
Not recorded.....	16	3,296	3,312
Sand, " <i>Clinton</i> ," <i>Whirlpool</i>	32	3,312	3,344

The Ohio Fuel Gas Company in 1918 drilled a dry hole on the Cline property in the south central part of Section 12. The Chicago-Oreton Company on their property in the northwestern part of the township drilled three "Clinton" wells that were failures. Two of these were on Alman Run in the northwest part of Section 22. The No. 1 well, completed in 1918, made a good showing of oil and the No. 2, drilled the following year, yielded a small quantity of gas. In the latter well, however, the sand, when shot, filled with brine, thus causing its abandonment. The third test by this company was located in the northwest part of Section 35 and was completed in 1920. The "Clinton" sand was red in color, had fair thickness and porosity, but gave only a showing of oil.

Clinton Township.—Until recently little drilling was done to the deeper sands in Clinton Township. Gas in the "Clinton" sand was secured west of Wellston, Jackson County, and later in Vinton County near Hamden in sections 30 and 18.

The first "Clinton" test within the area was drilled in 1910 on the I. N. Bay farm on Little Raccoon Creek in the southeast part of Section 7. The sand, 11 feet in thickness, was reached at 2,576 feet but contained neither oil nor gas in paying quantity. The drill penetrated the red Medina shale and stopped at a depth of 2,666 feet. The record of a well drilled on land of the Puritan Brick Company in the northeast part of Section 21 is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Not recorded.....	948	0	948
Sand, <i>Berea</i>	42	948	990
Red rock, <i>Bedford</i> shale.....	100	990	1,090
Not recorded, <i>Ohio and Olentangy</i> shales.....	855	1,090	1,945
Limestone, <i>Big lime</i>	682	1,945	2,627
Water at 2,465 and 2,505 ft.			
Not recorded, <i>Rochester</i> shale.....	182	2,627	2,809
Limestone and shells, <i>Dayton and Brassfield</i>	10	2,809	2,819
Not recorded.....	24	2,819	2,843

	Thickness Ft.	Top Ft.	Bottom Ft.
Sand, "Clinton," <i>Whirlpool</i>	4	2,843	2,847
Not recorded.....	43	2,847	2,890
Shale, red, <i>Medina</i> , <i>Queenstown</i>	10	2,890	2,900
Total depth.....			2,900

Both the Berea and "Clinton" sands were dry. The well head was about 120 feet below the Vanport limestone and 787 feet above tide. Large areas of unprospected territory in the eastern and southern parts of the township may eventually prove to be productive.

Wilkesville Township.—The drill has reached the "Clinton" sand in only three places in Wilkesville Township, twice near Minerton and once near Wilkesville; hence the area has not been thoroughly tested. The first well was drilled in 1922, by the Ohio Fuel Gas Company on the property of John Lawler on the ridge in the southeast corner of Section 33. The sand was devoid of either gas or oil in paying quantity. The same company in January, 1923, completed a "Clinton" well which gave only a showing of oil on the J. A. Newsom farm in the east central part of Section 10. The drill starting 815 feet above tide reached the Vanport limestone at 263 feet, the Quakertown coal at 508, the Maxtons and at 561, the Berea sand at 1,306, and the Clinton sand at 3,450.

BEREA SAND

The Berea sandstone, known to the driller as the Berea sand or the Berea grit, was named by Newberry for deposits exposed near Berea in Cuyahoga County. The formation outcrops in a broad belt, extending from Ashtabula County west to Huron and thence south to Adams and Scioto counties on the Ohio River. Under deep cover in eastern Ohio it is also very persistent. It lies just above the Bedford shale which is the oldest formation in the Mississippian system of rocks and which is commonly recognized by the driller on account of its argillaceous character, its weak resistance to the bit, and its light gray, chocolate, or pink color. The overlying formation, the Sunbury shale or the Little Cinnamon slate of the driller, is also easily recognized by its brown to brownish black color and by the tough, flaky character of the chips. In general the Berea is a fine-grained, argillaceous, light to bluish gray sandstone which is moderately resistant to the bit. The deposits are made up of alternate layers of sandstone and shale, the former predominating, in quantity. The upper layer of sandstone known as the cap rock is often very hard and resistant. The thickness of the Berea formation varies from 5 to 200 feet. In these deposits many small pools of oil and gas are present in the eastern half of Ohio.

In Vinton County the Berea is a very persistent formation as it is reported in nearly every test made to such depths. The average thickness of the deposit is 34 feet and the usual measurement between 20 and 50 feet. The texture and composition of the stone penetrated in Vinton County appear to be much the same as that exposed on the outcrop to the west near Chillicothe. The formation dips both to the east and to the south. This is shown by the fact that the top of the Berea sand lies 217 feet above tide in the Ovitt No. 1 well in Section 10, Eagle Township; 295 feet below tide in the Hewett well in Section 34, Waterloo Township, Athens County; 33 feet above tide in the William Poland well in the northwest part of Section 3, south, Richland Township; and 491 feet below tide in the J. A. Newsom well in the east central part of Section 10, Wilkesville Township. At present, 1925, only three small pools have been found in the Berea sand in Vinton County. The largest of these is in the west central part of Brown Township in sections 29, 35, 34, 28, and 33; the second is just west of Bolins Mills in sections 2, 3, 32, and 33, Knox Township; and the third pool, with only a small number of wells is near Zaleski in Section 36, Madison Township.

Brown Township.—In Brown Township the Berea sand was the objective stratum of the driller in 56 tests and it was passed in 5 others that were drilled to the "Clinton." The results at present (1925) are 28 producing oil wells, 2 abandoned oil wells, 9 producing gas wells, 8 abandoned gas wells, and 8 dry holes. The producing field is in the west central part of the township along Raccoon Creek in sections 35, 29, 34, 28, and 33. The oil wells came in with an initial production of 1 to 5 barrels and are now pumping from one-fourth to 2 barrels. A few of the best gas wells had an initial flow of 1,000,000 to 1,500,000 cubic feet per day with a rock pressure of 200 to 300 pounds.

In the southeast corner of Section 35 the Ohio Fuel Gas Company drilled, in 1918, a small oil well on the farm of L. P. Backus. Four tests have been made in the southwest part of Section 29. The No. 1 well on the B. A. Myers farm gave oil in paying quantity and the No. 2 well only a showing. The work was done by the Ohio Fuel Gas Company in 1918. On the adjacent property of G. P. Drayer a fair gas well was drilled by the owner in 1919 but the flow rapidly decreased and caused its abandonment in 1923. In the deep well drilled by the Pure Oil Company in 1922, the Berea sand gave a production of $1\frac{1}{2}$ barrels of oil per day and the "Clinton" sand 200,000 cubic feet of gas. In its continuation southward this Berea pool extends across the eastern half of Section 34 where 13 wells have been drilled along the valley of Raccoon Creek. The first test was made about 1895 on the Frank P. McGee farm. The well gave a strong flow of gas but as no use was made of the fuel at that time the casing was pulled. On

the same property but farther north the Logan Natural Gas Company obtained in 1918 a gas producer which is still flowing, and which now (1925) has a rock pressure of 45 pounds. These tests led to further drilling on this property with the result that oil was secured in four wells and gas in one. The log of the McGee No. 5 well is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	35	0	35
Sand and lime.....	327	35	362
Sand, <i>Big Injun</i>	46	362	408
Shale and shells.....	412	408	820
Shale, black, <i>Sunbury</i>	25	820	845
Sand, <i>Berea</i>	4	845	849
Total depth.....			849

The altitude of the well head is 730 feet and its stratigraphic position not far below the horizon of the Lower Mercer limestone. In the southeast corner of Section 34 on the Stevens property two gas wells and one dry hole were drilled by the Ohio Fuel Gas Company. One of these wells is still producing about 50,000 cubic feet of gas per day but the other was abandoned in the spring of 1925. Near by on the George Stein farm the Logan Natural Gas Company brought in two producers in 1921, but one of these was "pulled" in 1925.

The Berea sand in the area west of this in Section 28 has proved to be a good producer of oil and has also yielded some gas. In all, 24 Berea wells and one "Clinton" test have been drilled since 1914; only one of these was a failure and that more through flooding by water than the absence of oil. The present production (1925) is 11 barrels of oil per day from 16 wells and about 600,000 cubic feet of gas from 5 wells. Three other wells also produced gas for a few years. On the H. E. Pence farm the Preston Oil Company drilled 9 wells and the Logan Natural Gas Company 4. The other 12 wells were drilled by G. P. Drayer on his own land. The record given below is that of the H. E. Pence No. 8 well drilled by the Logan Natural Gas Company in July, 1917:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	34	0	34
Coal blossom, <i>Upper Freeport</i>	1	34	35
Clay and shale.....	25	35	60
Shale.....	80	60	140
Sandstone.....	50	140	190
Shale.....	125	190	315
Limestone, <i>Maxville</i>	40	315	355
Shale.....	120	355	475
Sand, <i>Big Injun</i> , <i>Black Hand</i>	125	475	600
Shale.....	220	600	820

	Thickness Ft.	Top Ft.	Bottom Ft.
Shells.....	20	820	840
Shale.....	110	840	950
Shells, <i>Hamden</i>	45	950	995
Shale, brown.....	25	995	1,020
Shale, black, <i>Sunbury</i>	30½	1,020	1,050½
Sand, <i>Berea</i>	1½	1,050½	1,052
Total depth.....			1,052

This well had an initial production of 877,100 cubic feet of gas per day and a rock pressure of 290 pounds. The well head is 980 feet above tide and the sand about 70 feet below this level.

In its continuation southward this Berea pool extends into the northeastern part of Section 33 where 10 Berea wells and one "Clinton" have been drilled since 1913. On the S. W. Wrightsel farm oil was found in three tests by the Ohio Fuel Gas Company and only a showing in another. The Preston Oil Company drilled two oil wells and one dry hole on the C. N. Pence property and two oil wells and one gas well on that of J. M. Elliott. The log of well No. 2 on the latter farm, drilled in 1920 by the Preston Oil Company, is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	25	0	25
Coal, <i>Middle Kittanning</i>	5	25	30
Shale.....	35	30	65
Coal, <i>Lower Kittanning</i>	8	65	73
Shale and sandstones.....	477	73	550
Shale.....	222	550	772
Sand, <i>Cuyahoga</i> in part.....	17	772	789
Shale.....	232	789	1,021
Sand, <i>Berea</i>	3	1,021	1,024
Total depth.....			1,024

The head of this well has an altitude of 895 feet. The initial production was 2 barrels and the present output is about 1 barrel per day. Scattered tests of the Berea sand have also been made in sections 21, 25, and 26.

Madison Township.—Prospecting with the drill in Madison Township led in 1916 to the opening of a small Berea pool near Zaleski in Section 36. In the next three years oil was obtained in 11 wells, gas in one, and only a showing of oil in one. These tests were all made by the Preston Oil Company on the property of E. W. Strong. The largest wells had an initial production of about 5 barrels per day. At present (1925) the total yield from the 10 wells still being pumped is about 5 barrels daily. The record of the Preston Oil Company's No.

12 well located on the E. W. Strong property near the central part of Section 36 and drilled in October, 1917, is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	45	0	45
Coal, <i>Clarion</i>	6	45	51
Shale.....	129	51	180
Sand.....	55	180	235
Sand and limestone,? hard.....	20	235	255
Water at 238 ft.			
Shale.....	15	255	270
Limestone, <i>Maxville</i>	5	270	275
Shale.....	430	275	705
Sand.....	95	705	800
Shale.....	205	800	1,005
Shale, black, <i>Sunbury</i>	26	1,005	1,031
Sand, <i>Berea</i>	5	1,031	1,036
Total depth.....			1,036

The well head is 880 feet above tide and near the horizon of the Lower Kittanning coal. The Berea sand is overlain by 25 to 30 feet of Sunbury shale, which on account of its dark brown color is known as the Little Cinnamon. The oil in the Berea sand is in the upper part of the stratum, usually from 3 to 6 feet below the surface. The lower portion of the formation is charged with brine. In both shallow and deep tests made in the east central part of Section 36, gas was encountered in the Berea sand. In the Preston Oil Company's No. 17 well drilled in January, 1919, the initial flow was about 200,000 cubic feet per day, but due to the presence of salt water the well was abandoned in May, 1925. The Berea sand was reached at a depth of 912 feet or 132 below sea level. Gas was found in the first 3 feet of the formation.

Near Prattsville in the northeastern part of Section 26, on the farm of George Verigan, a test of the Berea sand was made in 1895 but neither oil nor gas was secured. In one of the "Clinton" wells drilled near Vinton Furnace a small flow of gas was liberated in the Berea sand. Further drilling in Madison Township may show the presence of other small pools of oil and gas, as much of the area is as yet not thoroughly tested. No large structure is evident within the territory but minor deflections are present in several localities.

Knox Township.—Through the activity of the Ohio Oil Company a small pool of oil was found in the Berea sand near Bolins Mills in central Knox Township. The first test was made in 1900 on the J. N. Staneard property which is located in the southwest part of Section 33. Since that date 37 wells have been drilled in the township and at present,

1926, the tools are active in extending the field both to the north and to the south. Most of the wells had an initial production of 2 to 10 barrels per day but the average yield of those now being pumped is about one-half barrel per day.

The Ohio Oil Company between 1900 and 1919 drilled 7 producing oil wells and 2 dry holes on the J. N. Staneard property in Section 32, and 6 producers and 1 dry hole on the same lease in Section 33. The results on the farm of H. J. Radcliff in Section 2 were also favorable as 5 small oil wells were secured in 6 tests. This company also has one producer on the W. M. Beckley farm located in the southeast part of Section 3. The Devaughn Oil Company, in 1917 drilled two wells, one with an initial production of 5 barrels and the other of 2 barrels, on the L. H. Quick land in the eastern part of Section 2. Recently 1 dry hole has been drilled in the east central part of Section 34 and 2 dry holes and 1 well with a small flow of gas on a tributary of Onion Creek in the eastern part of Section 28. Just east of Bolins Mills the drill has also released a small flow of gas but as yet no oil. The main pool appears to extend southward into Section 1 where production has been secured in three wells operated by the Beeghley-Shaffer Oil Company. The log of the William Dearth No. 1 well completed by them in March, 1926, is given below:

	Thickness Ft.	Top Ft.	Bottom Ft.
Not recorded.....	250	0	250
Sand and not recorded, with gas at top.....	305	250	555
Sand, <i>Big Injun</i>	370	555	925
Not recorded.....	206	925	1,131
Shale, black, <i>Sunbury</i>	13	1,131	1,144
Sand, <i>Berea</i>	5	1,144	1,149
Total depth.....			1,149

The flush production of this well was $11\frac{1}{2}$ barrels. The altitude of the well head is 812 feet and its position near the horizon of the Upper Freeport coal and about 100 feet below the Brush Creek limestone. Another well near by, aside from the oil, gave 94,560 cubic feet of gas per day.

Vinton Township—The Berea sand has been the objective stratum in 7 wells drilled in Vinton Township and has been passed in 6 others that went to the Clinton. The results have been encouraging but have not been successful in developing a pool of either oil or gas. In 1895 H. C. Chapman drilled a well on Elk Fork near the mouth of Flat Run in Section 24. The sand reached at a depth of about 1,000 feet gave only a showing of oil but a heavy flow of salt water. In the same year near Eakin Mill in Section 10, Mr. Chapman put down a

second test to the Berea formation. It made a good showing of gas in the upper part of the sand but only brine in the strata below. The log of this well follows:

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil.....	25	0	25
Sand.....	35	25	60
Coal, <i>Brookville</i>	3	60	63
Limestone?.....	8	63	71
Shale, black.....	20	71	91
Sandstone.....	27	91	118
Shale.....	45	118	163
Sandstone.....	6	163	169
Coal, <i>Quakertown</i>	2	169	171
Shale.....	63	171	234
Sandstone.....	21	234	255
Shale.....	6	255	261
Limestone?.....	81	261	342
Shale.....	33	342	375
Sandstone.....	80	375	455
Sand, <i>Big Injun</i>	340	455	795
Shale.....	220	795	1,015
Sand, <i>Berea</i>	38	1,015	1,052
Shale.....	3	1,052	1,055
Total depth.....			1,055

Drilling started near the horizon of the Vanport limestone at an altitude of 640 feet. The Ohio Oil Company, in 1899, completed a test on the farm of William Arbaugh in the northwest part of Section 9 and another on that of Martin Pierce in the north central part of Section 13 but in these only a showing of oil was obtained. On account of the recent development of the Fisher pool in Athens County, work started again near Eakin Mill in Vinton County. On the G. McLaughlin farm in Section 10 the Myers Oil and Gas Company drilled one Berea well in 1924 and another in 1925 but neither was a success. South of Vales Mills, in the south central part of Section 4, more favorable results were secured on the P. McLaughlin property. Drilling is still in progress in this vicinity.

Wilkesville Township.—Aside from the three Clinton wells the Berea sand has been tested at only one place in Wilkesville Township, which is near Minerton in the southeastern part of Section 27. This well was drilled about 1895 and is reported to be approximately 1,300 feet in depth and to have made a showing of gas which is still escaping through the drive pipe.

HAMDEN SAND

In the Mississippian system sandstones appear with some regularity in that part of the section from 100 to 200 feet above the Berea

formation. Through local changes in character and through structural relations, one or more of these strata may become a reservoir for the accumulation of oil or gas. On this general horizon, but not directly correlative, belong the Wier sand of West Virginia, the Hamden sand of Pike, Jackson, and Vinton counties, the Welsh stray sand of Monroe County, and the stray sand of Columbiana County, Ohio. In southern Ohio the Hamden sand is a part of the Cuyahoga formation and lies on the average about 100 feet above the Berea sandstone. It consists of a number of distinct layers separated by shale partings. The sandstone strata vary from a few inches to 4 feet in thickness, from fine to medium coarse in texture, and from light gray to brown in color.

The Hamden pool is located northwest of the village of Hamden in western Clinton and southeastern Richland townships, Vinton County, and in northern Washington Township, Jackson County. In this area drilling began in the early sixties and has continued in a desultory way since that time. The main pool, however, was really opened in 1901 and was well developed by 1915. That part of the Hamden pool in Vinton County contains about 70 wells of which approximately 55 have yielded gas in commercial quantity. In most of the area the sand is found at a depth between 600 and 800 feet. The main production is located in sections 25, 26, 36, 35, 34, 33, 1 south, 2 south, 3 south, and 4 south, Richland Township, and sections 7, 18, and 19, Clinton Township. The initial flow of these wells was from 100,000 to 1,000,000 cubic feet per day and the rock pressure from 200 to 300 pounds. The pool is now (1926) largely exhausted.

BIG INJUN SAND

The Big Injun sand, widely known to the driller in eastern Ohio and northern West Virginia, is correlative with the Black Hand conglomerate which outcrops so prominently in this State in Licking, Fairfield, and Hocking counties. Where typically developed it is a coarse-grained, conglomeratic sandstone varying from 50 to 200 feet or more in thickness. It acts as a depository for oil and gas in a few fields in eastern Ohio. In Vinton County the Big Injun sand has shown promise in only one area, near Eakin Mill in Vinton Township, where some gas and much water were encountered in the stratum.

In one of the pioneer wells in Vinton County the drill on entering the Big Injun sand released a strong flow of gas which issued for many years. Andrews' account of this well in 1870 follows:¹

"An oil well was bored in 1867 on the land of John Calvin (now owned by L. A. Arbaugh) in Section 10, Vinton Township. At a depth of 95 feet a seam of coal was reported measuring 5 feet in thickness. At a depth of 490 feet a fissure containing gas was struck. The gas rushed up with great force and took fire from the engine fire,

¹Geol. Surv. Ohio, Rep. of Progress, 1870, p. 118.

40 feet distant, and burned to a height variously estimated from 75 to 200 feet. The burning continued for a fortnight, and caused no little consternation among the people of the neighborhood. The gas is still (1870) emitted with great force. It seems a great pity that so much heating and illuminating power should go to waste."

Regarding this well in later years Bownocker states:¹

"About ten years after the well had been drilled, during all of which time gas had been wasting, it was cleaned out with the idea of using the gas in the manufacture of lampblack. However, the time had passed for such a supply, and the well soon ceased flowing entirely."

Just east of the pioneer well the Myers Oil and Gas Company in September, 1924, drilled a test on the G. McLaughlin land in hope of securing production in the same gas-bearing stratum. The Big Injun sand made a good showing of gas but contained so much water that the well was abandoned. Drilling started near the horizon of the Vanport limestone at an altitude of 660 feet and stopped in this sand at a depth of 460 feet. Several of the Berea wells drilled in this locality also gave small flows of gas from the Big Injun sand but the gas is directly underlain by brine. In this area the sand is uncertain in extent, variable in thickness, and usually highly charged with salt water. As the texture of the sand is coarse, the flow of gas is rapid. The rock pressure as reported is from 100 to 200 pounds.

MAXTON SAND

The Maxton sand, named for an oil-bearing stratum on the Maxton farm near Sistersville, Tyler County, West Virginia, appears to be correlative with the Sharon conglomerate. In southern Ohio the Sharon member is well developed in local areas in Pike, Jackson, and Scioto counties. East of this under deep cover such rocks occasionally become depositories for oil or gas.

In Vinton County a small pool of gas has been found by the drill in the Maxton sand or Sharon member near Wilkesville, in Wilkesville Township. The best wells are located on the J. A. Newsom farm in Section 10, and were drilled by the Ohio Fuel Gas Company. The sand lies on the average about 285 feet below the Vanport limestone and about 40 below the Quakertown or Wellston coal. In the No. 1 well drilled on the Newsom farm in May, 1922, the initial flow of gas was gauged at 998,790 cubic feet per day. The rock pressure of the well was 140 pounds. In this test, starting 675 feet above tide, the Clarion coal was reached at 105 feet and the Maxton sand at 400 feet. The bit penetrated the sand 7 feet before work was suspended. The record of the Newsom No. 2 well, completed in July, 1922, is given below:

¹Geol. Surv. Ohio, Fourth Series, Bull. 1, p. 276.

	Thickness Ft.	Top Ft.	Bottom Ft.
Soil and shale.....	16	0	16
Shale, white.....	14	16	30
Sand, <i>Freeport</i>	10	30	40
Shale, green.....	5	40	45
Shale, light.....	105	45	150
Sand, <i>Macksburg Stray?</i>	50	150	200
Limestone, <i>Vanport</i>	5	200	205
Coal, <i>Clarion</i>	5	205	210
Clay and shale.....	42	210	252
Coal, <i>Brookville</i>	8	252	260
Shale, light.....	90	260	350
Sand, <i>Salt</i>	50	350	400
Shale, light.....	65	400	465
Shale, black.....	19	465	484
Sand, <i>Maxton</i>	12	484	496
Total depth.....			496

The initial flow of gas in this well was 2,251,000 cubic feet per day and the rock pressure 155 pounds. The altitude of the well head is 765 feet. In the third test on this property the flush production was 900,000 cubic feet of gas. The drill, starting 755 feet above tide, struck the Vanport limestone at 180 feet; the Clarion coal at 185 feet; the Brookville coal at 233 feet; the Quakertown coal at 425 feet; and the Maxton sand at 462 feet. In the Nos. 4 and 5 wells only shows of gas were encountered in the Maxton sand. The Ohio Fuel Gas Company also drilled a well to this sand in October, 1922, on the Hannah Forest property located in the northeastern part of Section 10. The flow of gas was too small to be commercially valuable. The record below shows the position of the Maxton sand with reference to the Quakertown or No. 2 coal and the well-known Vanport limestone.

	Thickness Ft.	Top Ft.	Bottom Ft.
Shale and not recorded.....	115	0	115
Limestone, <i>Vanport</i>	5	115	120
Coal, <i>Clarion</i>	5	120	125
Not recorded.....	235	125	360
Coal, <i>Quakertown</i>	2	360	362
Sand with water.....	18	362	380
Not recorded.....	24	380	404
Sand, <i>Maxton, Sharon</i>	45	404	449
Shale, dark.....	10	449	459
Sand with water.....	5	459	464
Total depth.....			464

The Maxton sand is also present in a few of the wells drilled in the western part of the township but as yet no production worth saving has been obtained. The stratum varies in texture from a medium fine sand to a coarse conglomerate, and is very unsteady in thickness and extent.

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